Least-Cost Planning Simulation Model

Division of Statewide Integrated Water Management
California Department of Water Resources

September 2010

DRAFT

Table of Contents

Appendices

Tables

Figures

Least-Cost Planning Simulation Model

LCPSIM Objective

The objective of the Least-Cost Planning Simulation Model is to assign an economic value at the Delta to water storage project alternatives that will allow them to be compared on the basis of their contribution to urban water supply reliability.

LCPSIM Model Concept

The Least-Cost Planning Simulation Model is a yearly time-step simulation/optimization model that was developed to assess the economic benefits and costs of enhancing urban water service reliability at the regional level. The LCPSIM output includes the economically efficient level of adoption of reliability enhancement measures by type, including the cost of those measures. The LCPSIM accounts for the ability of shortage event management (contingency) measures, including water transfers, to mitigate regional costs and losses associated with shortage events as well as the ability of long-run demand reduction and supply augmentation measures to reduce the frequency, magnitude, and duration of those shortage events. Forgone use is the difference between the quantity demanded and the supply available for use.

In the LCPSIM, a priority-based objective, mass balance-constrained linear programming solution is used to simulate regional water management operations on a yearly time-step, including the operation of surface and groundwater carryover storage capacity assumed to be available to the region. The system operations context allows the evaluation of the reliability enhancement contribution of additional regional long-term water management measures, including increased carryover storage capacity, to account for any synergistic interactions between measures. The cost of adding those measures is determined using a quadratic-programming algorithm which minimizes the cost of each incremental addition.

The LCPSIM was designed to be data-driven in order to easily represent different analytical circumstances without changing the model code. For example, adding a line of parameters to the carryover storage input text file is all that is necessary to create a new carryover storage operation. If unique situations require recoding, the source has been written with an emphasis on modularity to facilitate this.

Least-Cost Planning Strategy

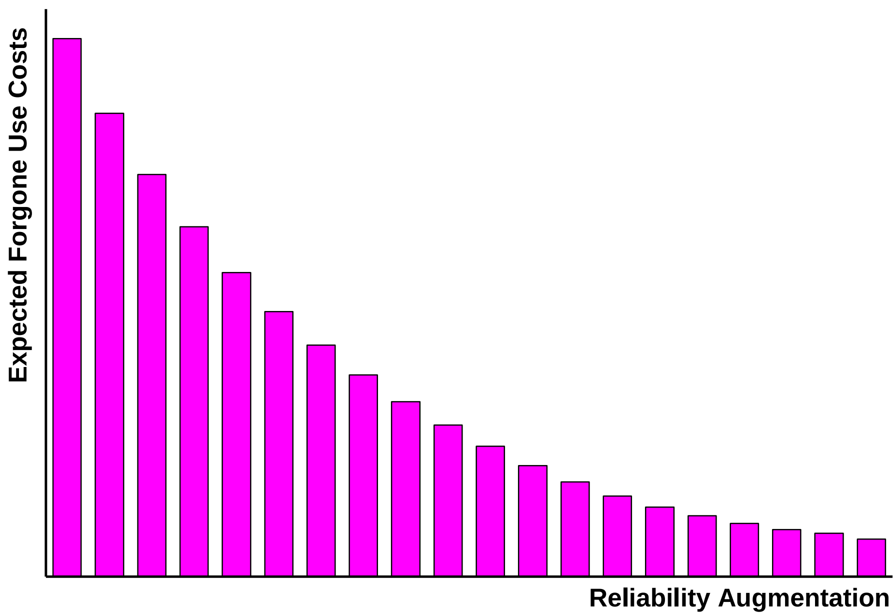
The primary objective of the LCPSIM is to develop an economically efficient regional water management plan based on the principle of least-cost planning. Under this principle, the total cost of reliability management is minimized. This total cost is itself the sum of two costs: the cost of reliability enhancement and the cost of unreliability, recognizing that the latter is inversely related to the former.

Using LCPSIM, an economic value can be assigned to a proposed program to augment imported supplies to a region; such an increase would allow a region to develop a water management plan on least-cost planning principles that would results in a lower total water management cost compared to the circumstances without the proposed augmentation program.

Forgone use is the most direct consequence of unreliability. Forgone use occurs when residential users or businesses, for example, have established a lifestyle or a level of economic production based on an expected level of water supply price and availability for use (i.e., quantity demanded) and the supply availability expectation is not realized in a particular year or sequence of years.

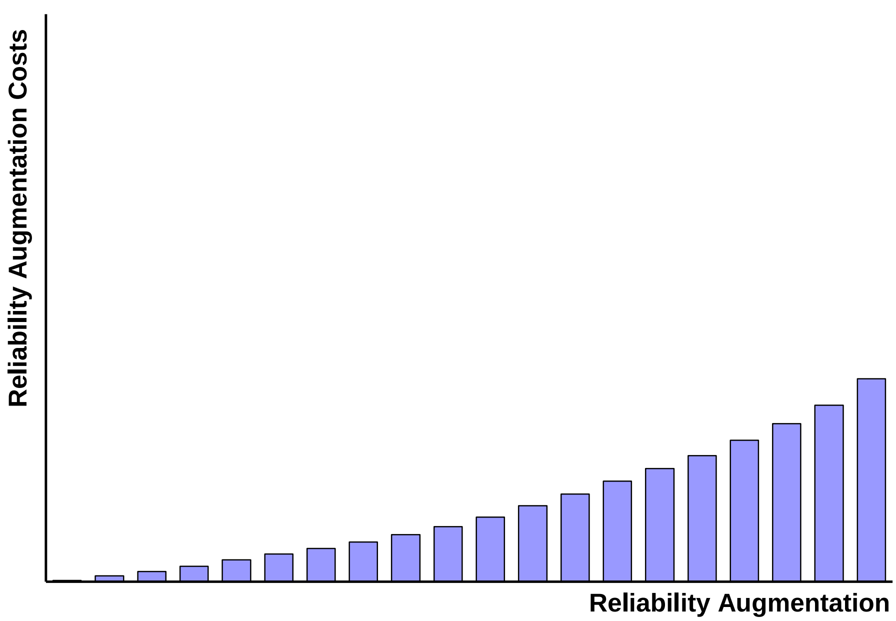
Figure 1 illustrates the expected decrease in the costs and losses associated with forgone use as regional water management options are adopted to enhance reliability. This enhancement may be obtained from either supply augmentation or demand reduction options.

Figure 1. The Effect of Increasing Reliability on Expected Costs and Losses



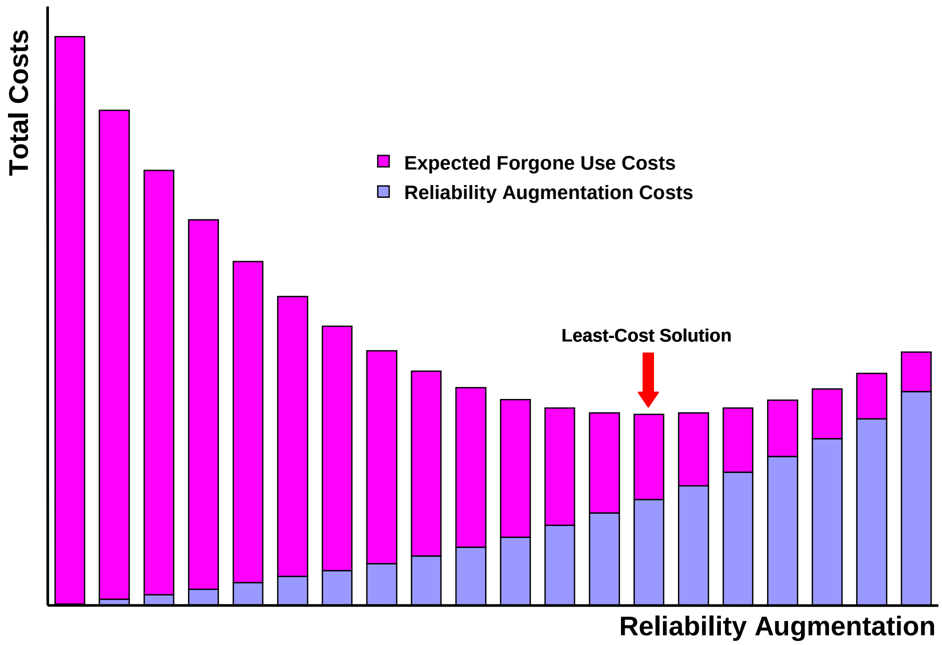
Depicted in Figure 2 is the incremental effect of augmenting reliability on regional long-run water management costs. The assumption is made that options will be adopted in an order inversely related to their unit cost: the least expensive options are expected to be adopted first.

Figure 2. The Effect of Increasing Reliability on Water Management Costs



Shown in Figure 3 is the result of combining the information from Figures 1 and 2 into regional total water management costs tied to the level of reliability enhancement.

Figure 3. The Effect of Increasing Reliability on Total Costs



The least cost solution is economically efficient, that is, it is the level of reliability enhancement beyond which it is economically less cost—compared to the cost of additional reliability enhancement—to accept the expected costs and losses from forgone use. Conversely, at any level of augmentation less than this, compared to the expected costs and losses from forgone use, it is less costly to enhance reliability.

LCPSIM as a Least-Cost Planning Tool

Modeled Relationships. At the least conceptually complex level, the relationship illustrated above related the effect of adopting long-run water management options such as recycling or toilet retrofit programs on costs and losses associated with shortage events. At a more complex level, the availability and use of contingency measures to mitigate the economic impacts of shortage events, such as short-term water market transfers, use of supplies from carryover storage (conjunctive use), and water allocation programs, for example, can affect the economically efficient level of adoption of the long-term water management measures. Conversely, the level of adoption of long-term measures can influence the effectiveness of the shortage contingency management measures and, therefore, their use.

Figure 4. Reliability Management Linkages

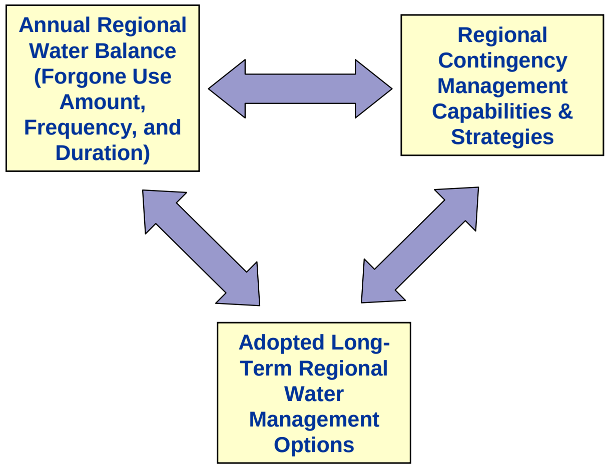
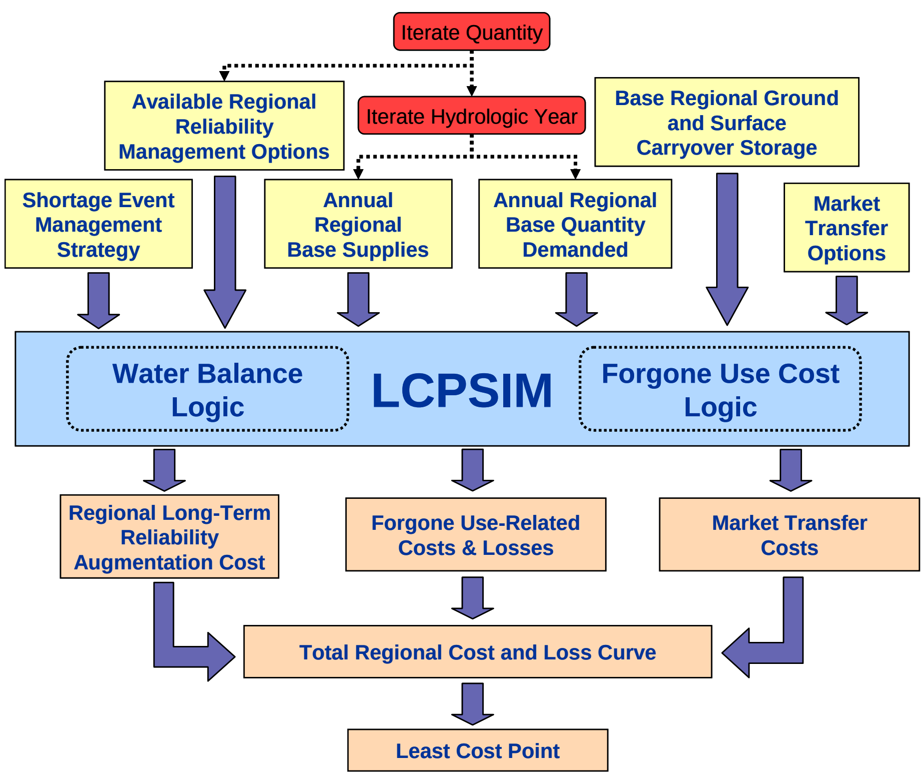


Figure 4 depicts the primary planning interrelationships important for evaluating, from a least-cost perspective, the cost of alternative plans to increase the reliability of a hypothetical water service system. The link between the investment in long-term water management options and the size and frequency of shortages is shown, as is the link between shortage contingency management abilities and the costs and losses associated with forgone use: a greater investment in the ability to manage shortages will lessen the economic costs and losses of due to forgone use when they occur.

The severity of these costs and losses are, in turn, linked to the willingness to invest in long-term water management options. Also, the larger the investment in long-term reliability enhancement, the less frequent and less severe will be the forgone use experienced, reducing the need to invest in the ability to manage shortages. Capturing a system with multiple sources of feedback, such as those which characterize the system outlined in Figure 4, is a complex problem.

Figure 5. LCPSIM Basic Elements



Basic Model Framework. Shown in Figure 5 are the basic elements of the LCPSIM used to generate the total costs and losses curve. This framework was used to attempt to capture the interrelationships depicted in Figure 4 to a reasonable level of realism for the South San Francisco Bay Area and South Coast Hydrologic Region, recognizing the trade off between reasonableness and both input data requirements and model complexity.

LCPSIM identifies the economically efficient level of reliability enhancement provided by long-term water management measures in the context of regionally available shortage contingency management measures. Regional reliability management measures are divided into three categories: (1) shortage contingency demand management (including demand reduction and reallocation of available supplies) and supply augmentation actions; (2) long-term demand reduction and supply enhancement; and (3) economic risk management. The latter strategy involves accepting a degree of economic risk from forgone use in order to avoid the use of other water management measures that are perceived to be even more costly. The least-cost combination of economic risk, regional long-term water management facilities and programs, and shortage management actions is identified within the model for each alternative water management plan being evaluated.

Specific Water Agency Operations Modeled

Modeled operations include deliveries to users, deliveries to and from carryover storage, water transfers, and shortage event-related conservation and water allocation programs.

Value of Water Delivered to Carryover Storage. Water supply in excess of demand for current consumptive use is allocated to ground or surface carryover storage, subject to storage constraints (i.e., annual put capacity and available space) associated with the individual storage operations available to the region. The stored supply generates economic value when its availability during future shortage events reduces the costs of contingency water management actions or the costs and losses due to forgone use.

Carryover Storage Operations. Shortage contingency management measures include the augmentation of current year deliveries with previously stored delivery quantities. In LCPSIM, use of carryover storage is limited to that amount that has been previously placed in storage or declared to be in storage at the start of the simulation. Carryover storage capacity can exist both in surface reservoirs and groundwater basins. The ability to use this storage is modeled using capacity constraints for reservoir and groundwater operations, and annual fill (put) and withdrawal (take) rate constraints for groundwater operations. By default, LCPSIM uses take capacity to stored supply ratios to dynamically set put and take priorities (see ***"Annual Priority-Weighted Mass-Balance Constrained Linear Optimization"***, below). LCPSIM can trigger water market transfers to refill depleted carryover storage.

> ***Banked Groundwater.*** A banking arrangement may involve an agreement between water agencies in two different regions of the State, for example, allowing one agency to operate a specified portion of the other agency's groundwater storage capacity (e.g. the agreement between the Santa Clara Valley Water District and the Semitropic Water Storage District). The stored water would be water that would otherwise be delivered for use under contract or water right but is stored for later delivery for use during shortage events. LCPSIM has the capability of simulating groundwater bank take constraints based on either quantity limits for consecutive takes (e.g., Arvin-Edison WSD) or on percentage cutbacks in SWP Table A deliveries (e.g., Semitropic WSD, Mojave WA). The rules for simulating these constraints are stored as LCPSIM data files.
>
> ***Regional Carryover Storage.*** This may be conjunctive use storage that is physically located within the region or it may be located outside of the region (e.g., Metropolitan Water District's Hayfield Project). Storage that uses a federal contract service conveyance facility (e.g., the

Colorado River Aqueduct) is constrained by the conveyance capacity available (federal contract deliveries are given priority).

Reserve Storage. In the South Coast Region, SWP terminal reservoir storage in the South Coast Region can be used for shortage management per contractual agreement. LCPSIM can place strict rules on the use and refill of this storage (i.e., the last to be used and the first to be refilled.)

SWP Carryover. If storage is available in San Luis Reservoir, SWP contractors can elect to have a portion of their SWP supply stored for delivery in the following year when the stored quantity is always assumed to be used to augment SWP deliveries. Available San Luis storage is determined using a file of time series data generated by CALSIM.

Conservation and Rationing Operations. These are measures that are instituted during shortage events or when the total carryover storage quantity available to meet a shortage event if it occurs in the following year (or years), is of serious concern.

Contingency Conservation Measures. Examples of contingency conservation measures include: alternate day watering regulations, water waster patrols, emergency water pricing programs, and intensive public education campaigns. A specified reduction in quantity demanded can be expected upon implementation of a program which includes such measures. The model assumes that such a program is instituted whenever there is a shortage in available water supplies compared to current quantity demanded or in response to low carryover storage availability.

Curtailment of Interruptible Deliveries. The economic losses assigned to users of interruptible supplies are assumed to be limited to the cost of that supply in accordance with their usual water rate. Interruptible program deliveries are assumed to be cut back along with non-interruptible deliveries but at a higher rate relative to non-interruptible cutbacks.

Contingency Water Market Transfers. Water market transfers are modeled using constraints as well as costs by source. These constraints include conveyance capacity, carriage water and other conveyance losses, and can be limited by the amount of water that can be transferred over a specified period or in consecutive years to emulate strategies for mitigating third-party impacts. If available, water costs by year type can be used.

Water transfers are also handled differently than other shortage contingency measures in the model. Using quadratic programming, a least-cost, economically efficient solution can be found for the sum of the economic losses to urban users and the total cost of the available supplies transferred. Alternatively, water can be transferred for shortage management using cost effectiveness. In both cases, quadratic programming is used to identify the least costly way to get a quantity of transferred water. Water transfers for the purpose of alleviating depleted carryover storage conditions are always based on cost effectiveness.

Rationing. In LCPSIM, "rationing" is shorthand for a water allocation method designed to minimize the overall economic costs of a shortage by "balancing" the costs of forgone use among customer classes. Above a specified threshold level, commercial users are assumed to forgo use at a lower percentage rate compared to residential customers. Industrial customers are assumed to forgo use at an even lower percentage rate. Conversely, water use for the purpose of maintaining large landscaping is assumed to be curtailed at a greater percentage rate than residential use. The allocation method in LCPSIM is intended to mimic water agencies either setting the allocation of the remaining supplies by user type or maintaining provisions for exemptions due to serious adverse economic impacts (e.g., layoffs) for businesses.

Economic Losses. A single residential user loss function is used for all user types to generate shortage event losses. Users in the commercial and industrial water use sectors–are, above a specified threshold shortage size, when their marginal losses are assumed to be substantially higher–allocated proportionately less of the overall forgone use during shortage events by the LCPSIM logic. This mimics the shortage contingency management programs used by local water agencies. These programs can be a pre-established cutback schedule by user type and/or a case-by-case cutback exemption program which is sensitive to avoidance of business income and job losses.

Elasticity of Demand. In LCPSIM, the cost of additional supply reliability and the cost of shortages (including forgone use and the cost contingency supply and demand management measures) affect the level of the use of long-term conservation measures beyond those included in the base use values. This is because the economic optimization logic used in the LCPSIM depends on comparing the marginal cost of regional long-term conservation measures and the marginal cost of regional supply reliability and the marginal expected cost of shortages. Quantity demanded is therefore a function of the overall regional water management efficiency. This is equivalent to the concept of price elasticity of demand but on an alternative marginal cost basis.

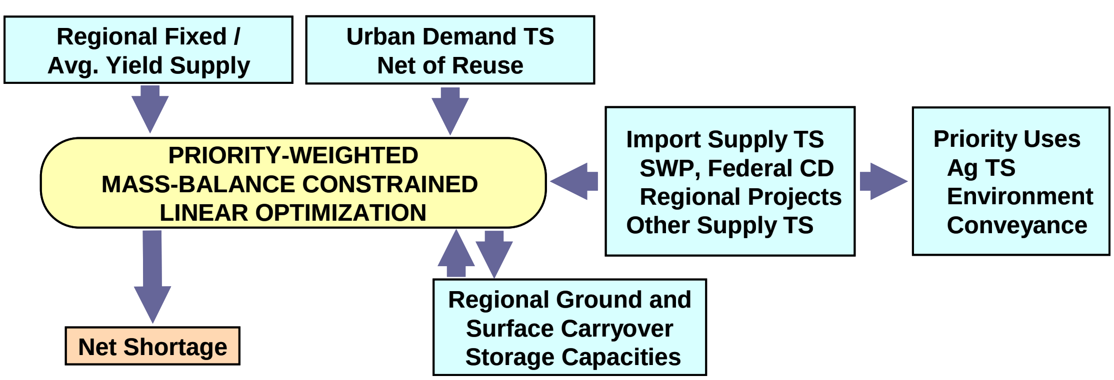
Demand Hardening. Long-term demand management measures that are adopted by water users can have a demand hardening effect. Although they can increase reliability by reducing the size, frequency and duration of shortage events, they can make these events relatively more costly when they do occur. A hardening factor can be set in the LCPSIM to simulate this effect (i.e., if conservation decreases demand by a specific percentage then the economic impact of forgone use of a specified size is computed as if the forgone use was greater.)

Unused SWP Supplies. The SWP and CVP water deliveries used by the LCPSIM are generated by the CALSIM project operations model. The CALSIM deliveries are driven by specified target delivery quantities which it tries to meet based on available inflows and storages on the SWP and CVP systems for each year of the hydrology used. Because these targets are set independently of the LCPSIM, an economically efficient water management plan can produce a level of reliance on regional supply and conservation measures which can result in the target deliveries for a region having been set too high for the wetter years. In these years, the capacity for deliveries to carryover storage can be exceeded, either because the volume to be stored exceeds the available space or the annual put rate is insufficient. This “excess” supply is assigned to the SWP because it is assumed by the LCPSIM to be the marginal supplier. This excess urban delivery quantity can be used to augment annual urban deliveries to other regions, to agricultural users, or used to reset the target deliveries in CALSIM II.

LCPSIM Simulation Logic

The following is a breakdown of the LCPSIM by its major logic elements.

Figure 6. Basic LCPSIM Water Management Simulation Elements



Basic LCPSIM Water Management Simulation Elements. Figure 6 represents the basic water management operations simulation elements in the LCPSIM.

Regional Fixed / Avg. Yield Supply: Water supplies include within-region surface and groundwater supplies exclusive of carryover operations expected to be available for the study year level (e.g., 2030). These supplies include recycling and groundwater recovery. Because of a lack of information about the year to year availability of the supplies from within-region reservoir storage and groundwater operations, they are included as long-term averages unless otherwise noted.

Import Supply TS (Time Series): Annual deliveries from projects which import water from outside the region including the State Water Project, federal service contract delivery projects, and regional projects. In the South Bay Area, the federal service contract delivery sequence represents CVP deliveries for the South Coast region, the sequence represents federal deliveries made through the Colorado River Aqueduct.

Other Supply TS (Time Series): Other variable supplies available to the region are included as annual quantities over the hydrologic period being represented (e.g., the 82 years represented by the period 1922 to 2003).

If available, the data used are produced by hydrologic modeling studies. State Water Project and Central Valley Project deliveries are developed by using CALSIM II, the Department's project operations model for the SWP and the CVP. Colorado River Aqueduct Deliveries were sent a long-term average based on the recent Quantification Settlement Agreement.

For the South San Francisco Bay Area, the regional variable supply sequence is developed from modeling done by the East Bay Municipal Utility District (Mokelumne Aqueduct) and the San Francisco Water Department (Hetch-Hetchy Aqueduct). For the South Coast Region, the regional variable supply sequence results from modeling done by the Los Angeles Department of Water and Power (Los Angeles Aqueduct). If a time series of regional groundwater availability (exclusive of conjunctive use operations) is available, the quantities can be added to this file.

A fourth supply file of "excess" SWP deliveries can also be used. If a portion of the SWP supply available to a region exceeds both current quantity demanded and available carryover storage capacity, a time series file of the excess quantities can be generated by LCPSIM for that region and used to augment SWP deliveries to another region.

Priority Uses: Uses which are assumed to be required to be met by regional supplies before the supplies are available for allocation to urban demands include non-interruptible agricultural use, environmental use, and conveyance losses. The supply needed to meet these uses is reduced by the regional reuse that occurs in the process of applying water for these purposes. LCPSIM uses a time series file of annual variation from average crop ETAW (Evapotranspiration of Applied Water) along with forecasted average applied water use from the parameter file to generate time series agricultural use data. Information on annual crop water use variation comes from a simulation model of unit crop ETAW that was developed to create a historical agricultural water use pattern for the 1922 to 2003 hydrologic period by water year (September through October). A reuse factor from the parameter file is used to generate the annual net agricultural use data used by LCPSIM.

Urban Demand TS (Time Series): The annual demand sequence consists of two components, non-interruptible, and interruptible demand. The demand sequence for non-interruptible urban deliveries is developed from a forecasted quantity demanded for the study level (e.g., 2030) being investigated. The annual interior and average annual exterior urban demand quantities are calculated using the interior and exterior urban demand share values from the parameter file. Interior demand is assumed to have the same value for all years. A value in the main parameter file allows for the separation of exterior use into two components, a fixed component, which is assumed to have the same value for all years, and a variable component, which is assumed to be directly proportional to the ETAW for each year.

A simulation model of urban turfgrass water use was developed to allow the creation of an annual ETAW variation time series for the 1922 to 2003 hydrologic period by water year (September through October). A variable exterior use component time series demand is generated using this time series and the average variable exterior demand. Adding the variable exterior demand time series to the sum of the fixed exterior demand component and interior demand produces the total urban applied water demand sequence.

Because the demand sequence consists of applied water quantities, they must be converted to net quantities for use in the mass balance logic. All of the variation in total applied water demand is assumed to arise from exterior applied water use. While the regional reuse associated with interior use is consequently constant, reuse associated with exterior applied water use varies from year to year. Interior and exterior reuse is calculated using factors from the parameter file.

The interruptible component of demand for the South Coast Region was developed from information contained in the annual financial reports of the Metropolitan Water District of Southern California. This component was held constant for the study period and the quantity specified assumes that other sources of supply will not be used in-lieu. No interruptible delivery program was assumed for the South San Francisco Bay Area.

Regional Ground and Surface Carryover Storage Capacities: The carryover storage element of the basic water management simulation algorithm was developed from information published by agencies within the study regions as well as discussions with their staff. The information obtained was used to estimate the average amount of groundwater basin and reservoir storage capacities available for the purpose of storing currently available water for use in future years. The carryover storage capacities are the amounts over and above the capacities needed for regional intra-year operations. In the same manner, annual rate ceilings for deliveries to carryover storage (puts) and withdrawals from carryover storage (takes) were developed.

Carryover storage operations can involve storage capacities within the region or external to the region. Puts involving groundwater storage can be accomplished by injection wells, spreading basins, or in-lieu deliveries (water users normally pumping groundwater are switched to surface water supplies). Conversely, takes from groundwater storage either can be accomplished by groundwater pumping or by switching water users who normally take surface water to groundwater pumping, allowing the now unused surface supplies to be delivered elsewhere.

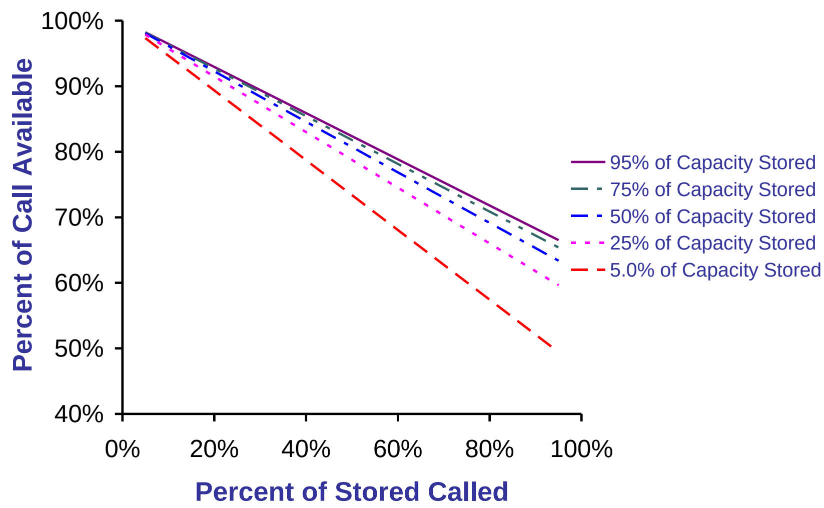
Information entered into LCPSIM for individual carryover storage operations includes the capacity which can be operated, the initial fill, the annual put capacity, the annual take capacity, the conveyance facilities which will be used for puts and takes, any losses associated with storage operations, the on-site unit cost of the put and take operations, and whether one or more storage operations operate the same physical storage space.

SWP project deliveries direct to San Joaquin Valley groundwater storage are also supported in LCPSIM. The stored water is then made available for delivery to the study region in subsequent years.

Additionally, LCPSIM can allow for water market transfers for the purpose of replenishing depleted carryover storage. A state of depletion is defined to exist if the total supply stored is less than the capacity to deliver that amount from carryover storage. A LCPSIM parameter setting determines the depletion threshold for this type of transfer to take place (e.g., carryover storage at 80% of the delivery capacity).

Takes from carryover storage are constrained in the LCPSIM to amounts accrued from puts in previous periods, with an allowance for a specified initial fill. Takes from carryover can also be constrained by a hedging function within the model. This hedging function can be assigned to any or all carryover operations but only on a total capacity basis. Figure 7 depicts the functional form used.

Figure 7. LCPSIM Hedging Function Example



From the example function shown, if the amount in storage is 50 percent of the total storage capacity of the operations selected to be hedged and 25 percent of the stored amount is needed to meet demand, 90 percent of the needed amount will be supplied. If 75 percent of the stored amount is needed, 70 percent of the needed amount will be made available. Three input parameters affect this function, the storage capacity ratio at which hedging is employed and two parameters which affect the absolute and relative slopes of the curves which relate quantity needed to quantity supplied.

Take constraints set in the carryover storage data file for reservoir storage can also be used to represent a specific hedging strategy. LCPSIM also accepts water bank take constraint rules based on either reducing the allowed take in consecutive-year take situations (e.g., Arvin-Edison WSD banking program) or on the project delivery received by the bank operator as a percentage of their contract full-delivery quantity (e.g., Semitropic WSD and Mojave WA banking programs)[1].

[1] Arvin-Edison's MWDSC take limit is reduced for each consecutive year for which a take is made. Semitropic's MWDSC take limit is equal to the bank's pumpback capacity plus the product of MWDSC's percentage share of the bank and Semitropic's SWP Contract Table A delivery after subtracting Semitropic's reserved amount of that allocation: Pumpback Capacity + Share of Bank * ((Table A Allotment * Percentage of Table A Delivered) - Reserved Table A).

Priority-Weighted Mass-Balance Constrained Linear Optimization: This model element is used to balance water use with water supply, simulating regional water management operations. Using the mass-balance logic requires that the demand data, which are applied water quantities, be converted to net quantities by accounting for regional reuse. Reuse is either fixed (e.g., recycling) or variable (e.g., in-region pumping of deep percolation). In LCPSIM, variable reuse arises primarily from deep percolation of exterior urban use (e.g., residential landscaping and public parks). The other variable source is interior urban wastewater that is deep percolated from septic tanks. For this conversion, interior use is assumed to be constant and any year-to-year variation in total use is assumed to arise from variation in exterior use do to weather (e.g., temperature and effective precipitation).

Storage operations are a critical component of the mass-balance logic. The put and take priorities for each storage operation are dynamically set by calculating the ratio of the stored supply to the take capacity for each storage operation for each annual time step. This ratio is then used to assign relative priorities for that time step: the lower the ratio, the lower the take priority and the higher the put priority. This strategy is designed to maximize supply availability from carryover storage when the desired deliveries to users exceed the supply available from other sources. Alternatively, these priorities can be set statically for each storage operation based on entries in the carryover storage data file.

Statically based priorities, in general, assume that when carryover supplies are needed to meet desired deliveries, water is preferentially taken from surface storage carryover supplies as opposed to groundwater storage carryover supplies. When supplies are available for refilling carryover storage, the supplies are preferentially used for groundwater storage carryover operations as opposed to surface storage carryover operations. Dynamically set put priorities are always used for water market transfers made to replenish depleted carryover storage, however.

If the water supply from the sources other than carryover storage is greater than desired deliveries to users then this balance can be achieved by needed deliveries to carryover storage. Deliveries to carryover storage are constrained by annual put ceilings and available carryover storage capacity after adjusting for put efficiencies (if less than 100 percent). The amount of supply remaining subsequent to this balance due to these carryover storage delivery constraints is used to estimate how planned SWP operations might be reduced in specific years compared to the target deliveries sent in CALSIM II.

If the supply from the sources other than carryover storage is less than desired deliveries to users, this balance can be achieved by deliveries from carryover storage or by reducing use or both. Deliveries from carryover storage are constrained by the annual take ceilings and the amount of stored water available. Desired deliveries are separated into three categories: base use deliveries, deliveries for contingency conservation affected use, and interruptible use deliveries. Contingency conservation affected use is that amount of non-interruptible use which can be expected to be eliminated on a short-term basis in response to programs such as drought alerts and conservation advice in the media, local agency water-waster patrols and alternate-day watering rules, etc.

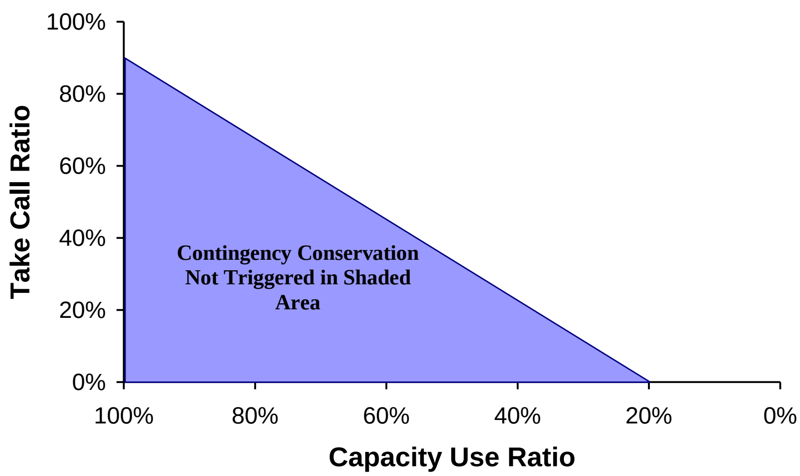
Although a mass balance constraint is used to assure that supplies equal uses (aside from any supplies excess to the quantity demanded that can't be delivered to carryover storage), how this balance is achieved is set by assigning priority weights to affect how the water is moved. The algorithm maximizes quantities weighted by priorities subject to the imposed system constraints.

To assure that failing to meet the quantity demanded for current base consumptive use is a "last resort", meeting it has a very high priority. Contingency conservation affected current consumptive use has a somewhat lower priority. Interruptible use has a relatively low priority compared to the other use categories. Even lower priorities are assigned to deliveries to carryover storage. Because of how it is used, however, a relatively high priority is given to reserve reservoir storage to insure it is refilled as quickly as possible, even if contingency conservation is still in effect.

On the supply side, water delivered from sources other than carryover storage is assigned the lowest priority (i.e., the model uses this source first). Next in priority are deliveries from carryover storage, with the weight scheme giving preference to deliveries from reservoir carryover.

Overriding the allocations based on weights are contingency constraints which are implemented to reflect contingency shortage management programs. One such contingency constraint is a function relating interruptible program cutbacks to the level of the supply made available for delivery to the non-interruptible uses. An input parameter in the model determines the level of reduction in deliveries to the non-interruptible uses at which point the interruptible program is zeroed out.

Figure 8. Trigger Function for Contingency Conservation

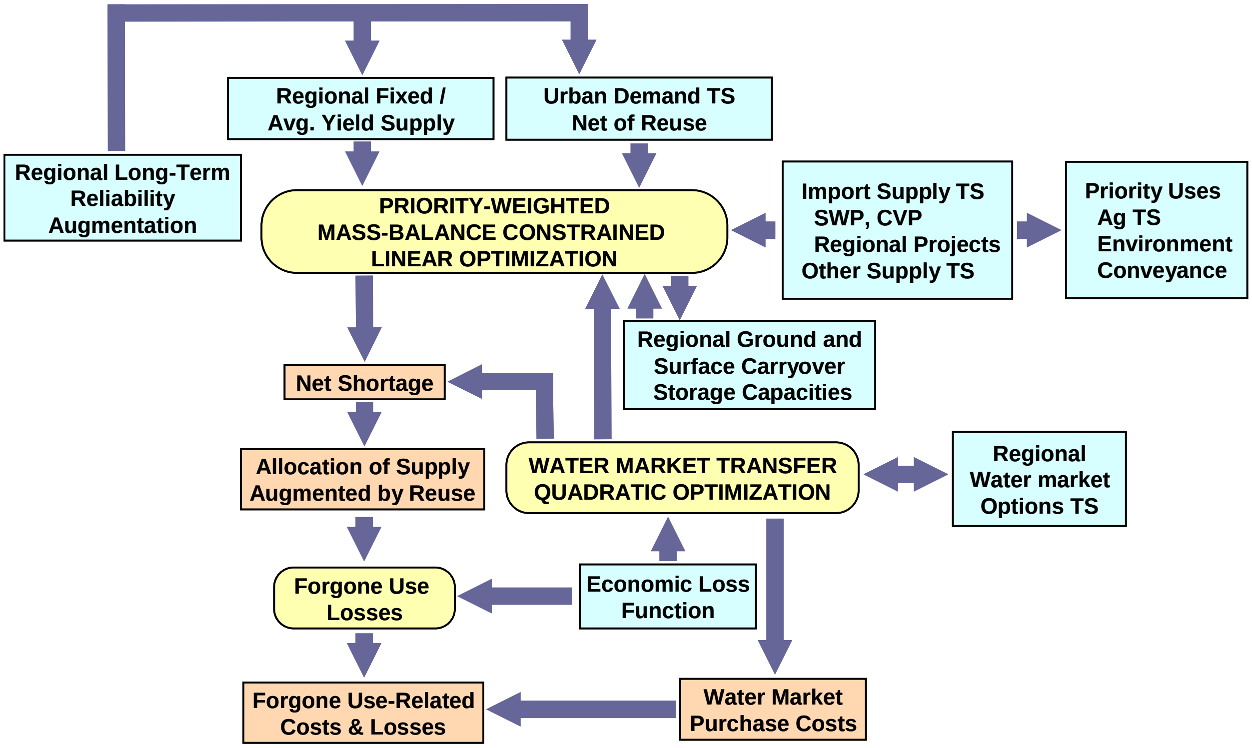


Another contingency constraint keeps carryover supplies from being delivered from reserve reservoir storage facilities. This category of storage is available for use only if supplies delivered from sources other than carryover are less than that needed for base and interruptible use plus the amount needed to refill any available reserve reservoir storage capacity. A contingency constraint is also used to curtail supplies allocated to contingency conservation affected use. This represents the institution of a contingency conservation program and allows supplies which would have been directed to this category of use to be allocated elsewhere. Shown in Figure 8 is the function used to implement this constraint. The take call ratio relates desired deliveries to supply availability, including the supply available from carryover storage but exclusive of water market transfers that have a shortage threshold constraint imposed. The capacity use ratio relates the total amount of capacity available to store carryover supplies to the total amount of water in carryover storage. Both of these ratios are input parameters to LCPSIM.

Shortage: After the mass balance is performed, there may not be sufficient supplies available from current year supplies and withdrawals from carryover storage to meet the quantity demanded. Before determining the economic losses from forgone use, the ability of contingency water market transfers to augment current year supply is simulated.

Regional Water Market Transfers and Economic Losses. Shown in Figure 9 are the elements from Figure 8 with the addition of elements used to simulate water market transfers and an element used to determine economic losses from forgone use.

Figure 9. Regional Water Transfers and Economic Losses



Regional Water Market Transfer Options TS (Time Series): Water market transfer options are input into LCPSIM in terms of the quantity available from a specified source, the cost obtaining the water at the source, what facilities will be used to convey the transferred water, any losses during conveyance (e.g., carriage water for transfers involving the Delta), and any constraints on the frequency of use of the transferred water from that source. Multiple sources can be used. Also, transfers which have a forgone use threshold constraint can be specified. System conveyance capacity constraints and delivery efficiency factors for water market transfers in the form of time series files generated by CALSIM or other system models can be used by LCPSIM. LCPSIM can use such files for transfers from the either Sacramento Valley, the San Joaquin Valley, or both.

The cost of obtaining the transferred water can be entered as coefficients of a quadratic function, representing the situation where the unit price increases linearly as the amount purchased is increased. If available, the cost data can be entered as a file of cost coefficients by year type.

Identification of the conveyance facility is needed to determine what capacity remains for moving the water to be transferred and to determine the conveyance cost. If the conveyance facility is a federal service contract facility that is used to convey exchanged SWP Table A contract deliveries then the aqueduct capacity for transfers is increased during those years when Table A deliveries are cut back. For example, MWDSC delivers Colorado River water to Desert Water Agency and Coachella Valley Water District through the Colorado River Aqueduct in exchange for their SWP contact deliveries.

Frequency of use constraints can be used to represent the need to respect the potential for serious third-party impacts. These constraints are specified by source and are in the form of a limit on the maximum amount of water which may be transferred during consecutive years and in terms of the maximum quantity to be made available over a ten year period. Both of these constraints are expressed as a percentage of the maximum to be made available during any single year event. Another third-party impact mitigation mechanism is a constraint that can be placed on transfer sources that restrict their use to shortage events which exceed a specified percentage of regional use. These constraint parameters are overridden if time-series transfer quantity constraint files are available.

Simulated water market transfers include not only those made for shortage event management but also those made to augment carryover storage. The latter type of transfer can be triggered when carryover storage is depleted (i.e., when the amount of stored supply is less than the available take capacity). The trigger can be set in the LCPSIM parameter file as a percentage of take capacity.

Forgone Use Allocation: After accounting for water market transfers, this model element is used to allocate forgone use resulting from the remaining shortage among the different user classes represented in the model: industrial users, commercial and governmental users, single family and multifamily residential users, and large landscape users. This allocation is determined by input parameters for the non-single family residential users. These parameters represent the respective fractions of the single family residential percentage of use forgone that will be allocated to them. For example, a parameter value of twenty-five percent for industrial users means that these users will be held to a forgone use equal to twenty-five percent of the percentage use forgone by single family residential users. This results in the single family residential users forgoing use, in percentage terms, larger than the overall forgone use. This effect can be moderated by specifying that deliveries to large landscape irrigators will be curtailed at a greater percentage rate compared to single family residential users. An input parameter determines the level of overall forgone use at which this allocation takes effect. This is intended to represent strategies used by water agencies to protect businesses and institutions from serious economic damage and job loss during shortage events. Some water agencies have explicit water allocation rules. Other agencies have hardship exemption programs that have a similar result.

Economic Loss Function: This model element assigns economic losses to forgone use. The loss function is input into LCPSIM either as coefficients of a polynomial function which relates a percentage forgone use to a total cost of that forgone use or as the coefficients of a constant price elasticity of demand function. Because the loss function is intended to approximate willingness-to-pay at the water user level, it is driven by the availability of applied water. For this reason, the net water supply availability generated by the mass-balance logic must be converted to applied water supply availability. This is done by adding reuse back to the net water supply.

LCPSIM logic accounts for the assumption that interior use that is cut back at a lower rate than exterior use during shortage events and that the associated reuse factors differ. Because recycling options affect fixed reuse, this also has to be taken into account in calculating the overall annual reuse quantities needed to related applied water supply availability to net water supply availability. The effect of the adoption of conservation options on the relationship between a shortage in supply and the availability of applied water is also taken into account in the determination of economic losses.

The LCPSIM has the ability to use a polynomial loss function because this functional form has the advantage of allowing “threshold effects” to be modeled. There is evidence from contingent valuation studies (SWRCB Bay-Delta Hearings, Exhibit 51 and others) that it is possible that the inconvenience of dealing with water agency policies during shortage events (e.g., alternate day watering and gutter flooder regulations, water waster patrols, etc.) is perceived as a hardship over and above the value associated with the amount of water no longer available for use. This phenomenon, if real, can be represented by a loss function in which, over a limited range, associates a higher rate of increase of the marginal value of supply at lower forgone use levels than at higher shortage levels.

The ability to use a constant price elasticity of demand function is also provided as an alternative, more conventional, means of representing demand (i.e., there is no “threshold effect”). It has the advantage of using just two parameters that are readily available from most econometric studies of water demand. This specification of the loss function results in the acceptance of an appreciably greater number of small shortage events at the least-cost LCPSIM solution compared to the polynomial function. Tables 1 and 2 show a comparison between results produced by the two functional forms.

For comparison, the elasticity value of -0.10 used for the CPED function was set to replicate the forgone use losses at 25 percent as determined by the polynomial function. (A 1996 elasticity study done for DWR Bulletin 160-98 found an average elasticity of -0.16 for urban residential users.)

Table 1. Example Polynomial Loss Function Values

	Willingness to Pay to Avoid Event		
	Acre-Foot Use/Year/Household		
Forgone Use	0.75	0.65	0.55
0%	$0	$0	$0
5%	$49	$43	$36
10%	$145	$126	$106
15%	$278	$241	$204
20%	$439	$380	$322
25%	$618	$535	$453
30%	$804	$697	$590
35%	$990	$858	$726

Table 2. Example CPED Loss Function Values

	Willingness to Pay to Avoid Event		
	Acre-Foot Use/Year/Household		
Forgone Use	0.75	0.65	0.55
0%	$0	$0	$0
5%	$29	$25	$22
10%	$79	$69	$58
15%	$166	$144	$122
20%	$323	$280	$237
25%	$618	$535	$453
30%	$1,194	$1,034	$875
35%	$2,376	$2,059	$1,742

When they occur, the calculated losses can be increased by a specified percentage amount to reflect the more severe consequences of consecutive shortage events of a size greater than another specified percentage amount. Both percentages are model input parameters. This effect falls off as a power function of the number of years between events and does not apply if the next loss event follows by more than two years.

The losses are also adjusted by the amount of demand hardening present in the system compared to the base. Hardening is computed from the ratio of the quantity of use reduction due to conservation to total quantity of use prior to that reduction and expressed as a percentage. This percentage is then multiplied by a percentage specified as a LCPSIM input parameter (the demand hardening adjustment factor) to get a forgone use adjustment factor.

This latter value is used to adjust the quantity of forgone use before the loss function is applied. For example, if pre-adjustment forgone use is ten percent, the demand hardening percentage is twenty percent, and the demand hardening adjustment factor is fifty percent, then forgone use is increased to eleven percent for the purposes of determining economic losses.

The unit value of the losses incurred by interruptible supply customers is the same as the unit price paid for that supply. This is based on the assumption that the price reflects the value of that supply discounted for unreliability by knowledgeable users of that source of supply.

Water Market Transfer Quadratic Optimization: If the mass balance algorithm results in insufficient supplies to meet desired deliveries, this model element is used to determine the total amount of water to be transferred to help meet the insufficiency. Unit water purchase costs from each source are adjusted upward by their respective conveyance losses and augmented by their respective conveyance costs. The unit purchase costs from any source can be specified as coefficients of a quadratic function, representing a unit cost that increases linearly as the amount used is increased. Quantities available from each source are constrained by the applicable conveyance capacities. The quadratic programming solution which minimizes the sum of the forgone use-related costs and losses and the costs of transfers is used to determine the quantity transferred to reduce forgone use.

Expected Costs and Losses Curve. Shown in Figure 10 are the elements from Figure 9 with the addition of iteration logic. The summation of water market transfer costs and forgone use costs and losses produces shortage-related costs and losses for an individual year. Iterating through the years in the hydrologic record produces expected costs and losses based on the level of adoption of regional long-term reliability augmentation options. Further iterating these expected values by incrementally increasing the level of adoption of regional long-term reliability augmentation options generates a downward sloping curve of expected costs and losses points as shown in Figure 11. Conveyance, potable and wastewater treatment, delivery, and carryover storage operations costs are included.

Figure 10. Expected Costs and Losses Curve Logic

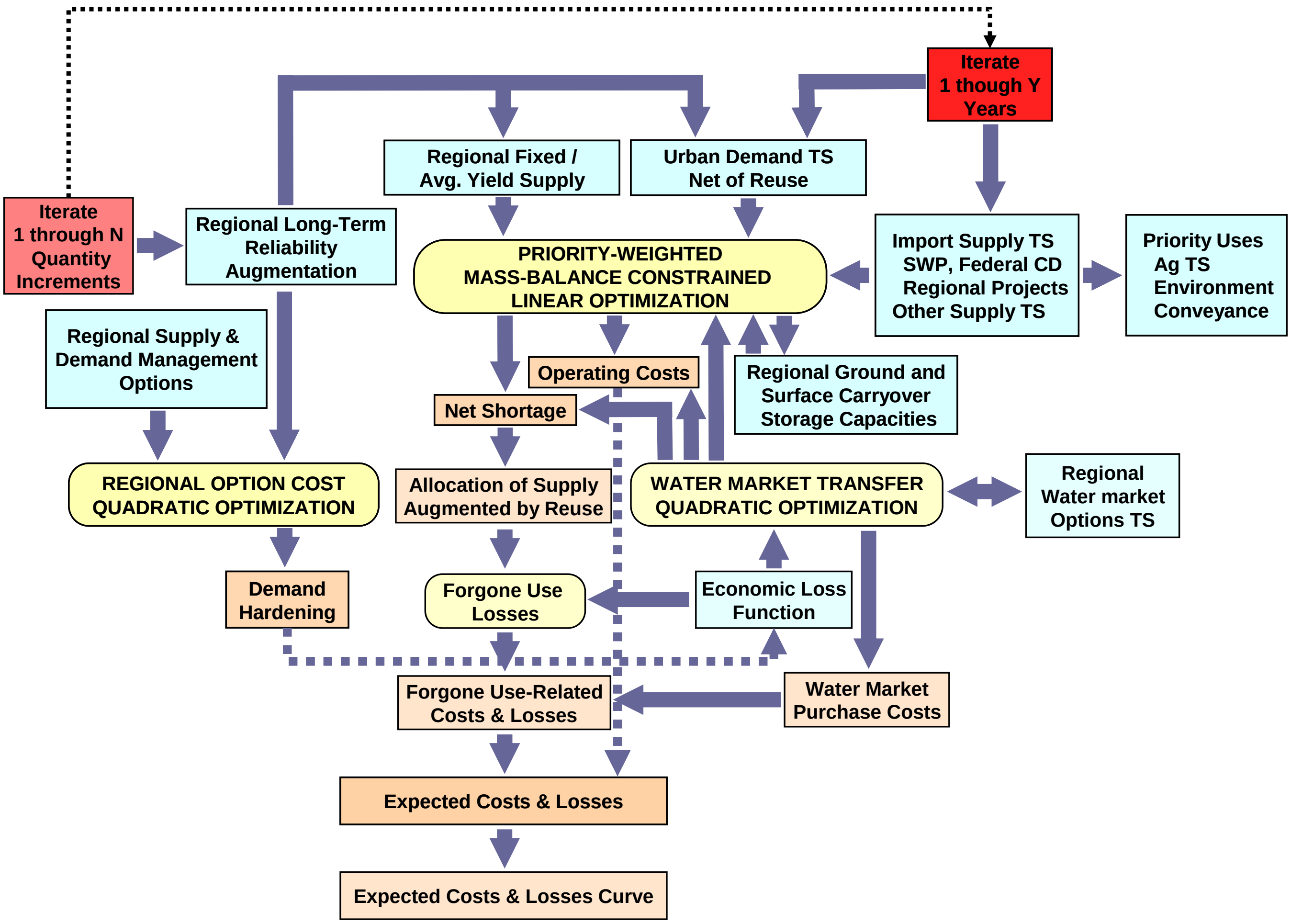
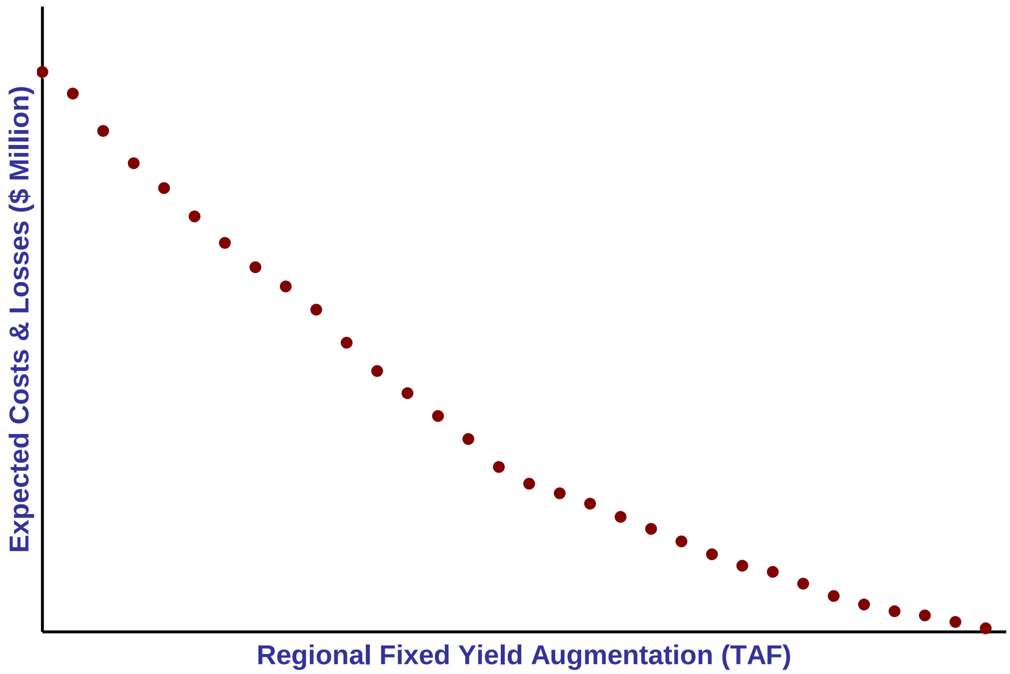
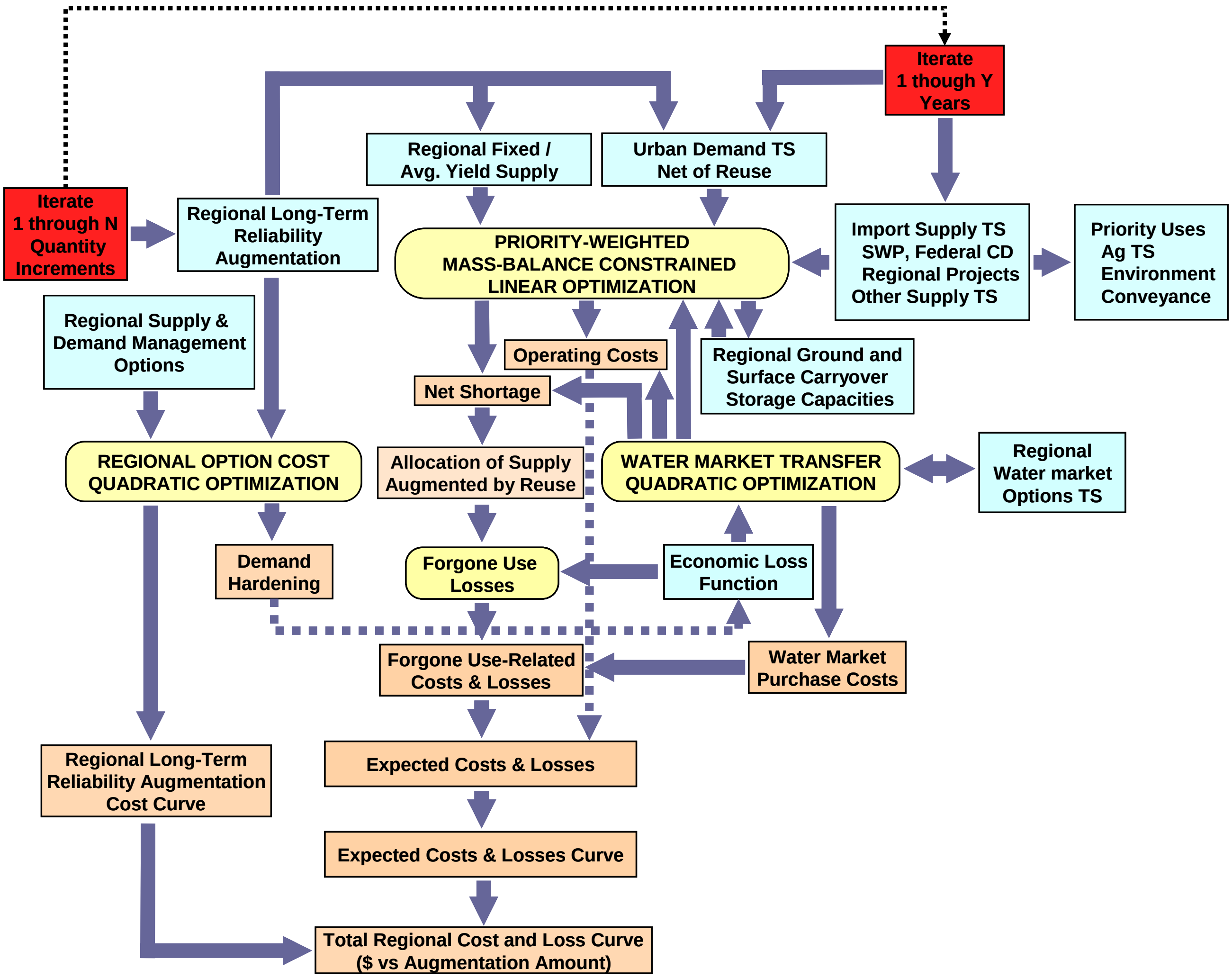


Figure 11. Expected Costs and Losses Curve



Total Regional Cost and Loss Curve. Shown in Figure 12 are the elements from Figure 10 with the addition of elements which can be used to either augment regional fixed yield supply or reduce regional demand, depending upon the type regional reliability management option used. This logic produces and upward sloping curve of reliability augmentation cost points. The costs of reliability augmentation are summed with the expected forgone use-related costs and losses to produce a saddle-shaped curve of total cost and loss points as shown in Figure 13.

Figure 12. Total Regional Cost and Loss Curve Logic



Regional Long-Term Reliability Augmentation with Regional Supply and Demand Management Options : This element adds an increment of a specified constant size of regional option use which either augments the regional supply by a fixed annual yield or reduces demand by a fixed annual quantity or does some combination of both. Information on individual regional water management options used by LCPSIM includes: the amount available from that that option, the unit annualized capital and O&M cost of that option, and the type of option.

The unit cost of any option can be specified as coefficients of a quadratic function, representing a unit price that increases linearly as the amount used is increased. The costs are from the perspective of statewide economic efficiency, and are lifecycle costs whenever possible. Conservation options, for example, are adjusted to reflect any energy costs savings which might accrue to the user.

The type of option is used to determine how the option would affect the mass balance. Options such as ocean water desalting augment supply, conservation options decrease applied water demand, and recycling options augment reuse. With one exception, these options are assumed to provide a fixed level of supply enhancement or demand reduction each year.

The type of option is also used to determine either the cost of regional potable water and wastewater treatment and distribution, or, in the case of conservation, that these costs don't apply. To determine the effect of conservation on wastewater treatment costs, interior and exterior conservation options are identified separately. If a recycling option has a dedicated distribution system (e.g., "purple pipe"), the capital and operations and maintenance costs of that system must be included in the option data file as the cost of that option. The regional potable water treatment and distribution costs would not apply.

The applied water that is "lost" to surface return flows and deep percolation can help meet applied water demand through reuse. Conservation options, by definition, reduce this loss and, therefore reduce this source of applied water. To account for this, the option file includes percentage values to account for the effect of reuse on the ability of water conservation options to reduce the need for regional supplies (i.e., net demand) and on the cost of achieving that reduction. For example, exterior use conservation options which support the same plants (i.e., same ETAW) but reduce return flows and deep percolation will have a different effect on the need for regional supplies compared to conservation options which substitute different, lower water using plants, even though the applied water reduction may be the same in both cases. Conservation options which reduce the amount of deep percolation are credited with their associated pumping cost savings in LCPSIM, reducing their effective cost.

The exception to fixed nature of the options used by LCPSIM is exterior conservation. The value in the main parameter file that sets the share of exterior use that is unaffected by ETAW is also used to separate the effect of exterior use conservation into a fixed component and a variable component. The variable component is assumed to be directly proportional to the amount of exterior use in any year and is intended to capture the effect of actions which, for example, reduce the amount of water applied through better irrigation management. In years dryer than average, the number of irrigations are likely to be higher, increasing the opportunity for better management to have a greater effect on use compared to wetter years. The quantity and cost entered into the options file is the average of the use reduction effect and cost of both conservation components.

Shown in Figure D-1, Appendix D, is an example of the use of a regional hydrologic balance modeling tool that was developed in Excel® for the purpose of setting some of the water use and reuse parameters LCPSIM. The model is calibrated with Regional Water Portfolio data gathered for DWR Bulletin 160, the California Water Plan Update. The model solves for an overall regional water supply requirement from within-region applied water use quantities after accounting for regional reuse.

The model logic incorporates circular references which require an iteration-based solution (e.g., the reuse of water applied to irrigate landscape is a function of the quantity applied; the need for applied water, in turn, is dependent on losses, a portion of which is reused as part of applied water requirement). After calibration, assumptions about future levels of water use efficiency and recycling can be used to develop base case conditions for LCPSIM parameters for 2030, for example, including the levels of supply-dependent interior and exterior uses; the effectiveness of interior and exterior conservation, respectively; and total regional reuse.

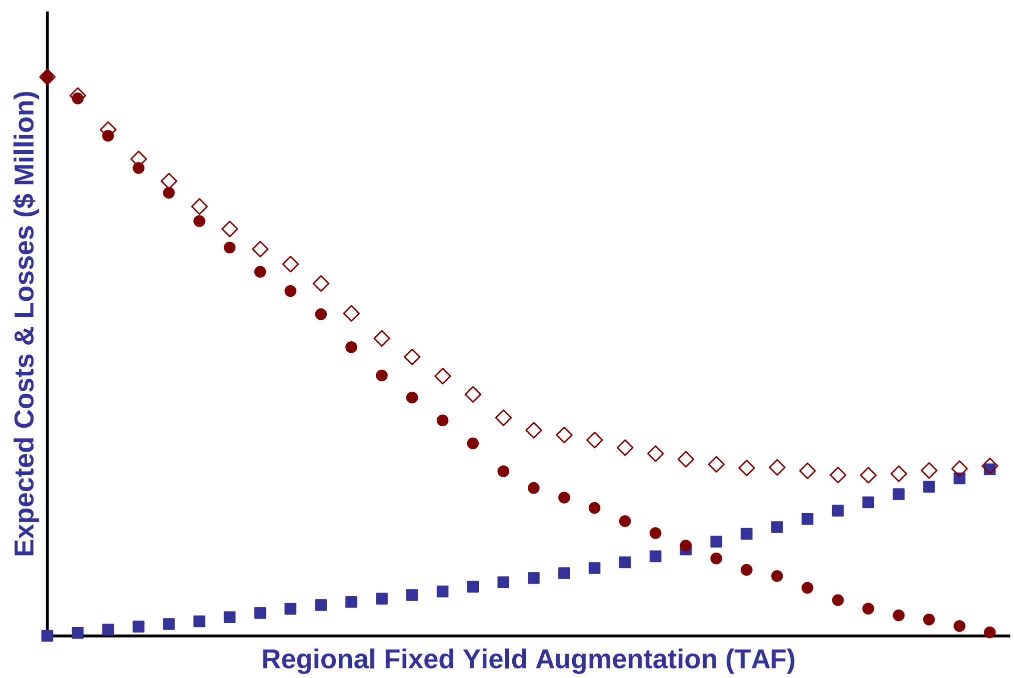
Regional Option Cost Quadratic Optimization: This model element is used by LCPSIM to relate the amount of option use to the total cost of that amount of option use. For a particular level of option use, the options are assumed to be implemented in manner that minimizes the cost of achieving that level of use when both annualized capital and O&M costs and regional potable water and wastewater treatment and distribution costs are considered. Because quadratic option costs can be entered, a particular level of use may be achieved by implementing less than the total amount specified as being available from any one option.

Demand Hardening: The amount of conservation included by the optimization routine is tracked and this information is used in the economic loss function element to adjust economic losses for demand hardening.

Incremental Regional Systems Operations Costs: The economic costs and losses related to forgone use for the changes in regional systems operations costs realized as a consequence of implementing the use of the local supply augmentation and demand reduction options are adjusted for changes in regional water management operations costs. These costs include SWP conveyance costs to the region, conveyance costs on other affected aqueducts supplying the region, and regional potable water and wastewater treatment and distribution costs. The conveyance costs include the cost of wheeling water market transfers.

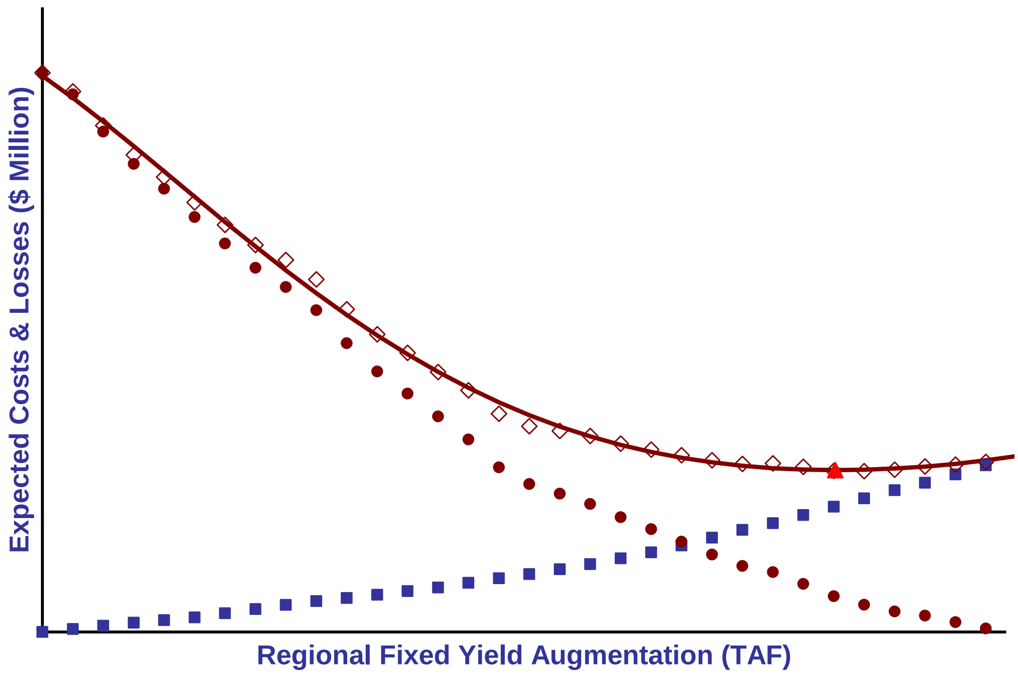
Unit costs of aqueduct conveyance, regional potable water and wastewater treatment and distribution costs are entered as LCPSIM parameters. Also entered are per-capita costs to regional water agencies to manage and rationing programs along with the forgone use threshold at which it assumed a rationing program will be instituted. The contingency conservation program cost is imposed whenever the water management simulation logic in LCPSIM cuts deliveries to the contingency conservation affected use category. The cost of managing a water use reduction exemption program is an example of a cost that would be incurred in a rationing program.

Figure 13. Total Regional Cost and Loss Curve



Solving for the Least-Cost Use of Regional Water Management Options. Figure 14 shows the result of applying a polynomial smoothing function to the total regional cost and loss curve points and then solving for the least-cost point (triangle):

Figure 14. Least-Cost Solution Point



The model also has the capability of solving for the point that meets specified hydrologic reliability criteria. This capability is useful for comparing the economic efficiency cost of (if any) of planning on the basis of hydrologic reliability criteria instead of economic efficiency. The reliability criteria are entered in LCPSIM by specifying one or more forgone use percentages and providing not-to-exceed frequencies for each forgone use percentage specified.

Results Available for Viewing and Saving: Both incremental and summary results are available in tabular form:

- LCPSIM input data by year and water year type average
  - Supply by source
  - Quantity demanded

- Detailed data by regional water management option use increment and by year
  - Supply
  - Carryover storage by location
  - Contingency conservation
  - Base and interruptible program use
  - Water market transfers by source
  - Percent forgone use
  - Forgone use-related costs and losses
  - Percent of available water market supply transferred by source

- Summary data by regional water management option use increment
  - Option use cost
  - Costs and losses from forgone use and water market transfer purchase costs
  - Regional system operations costs by cost component
  - Number of shortage events
  - Average sufficiency (1 – average forgone use)

- Total costs
- Fitted total costs (fitted polynomial smoothing function)
- Residual (total minus fitted total costs)
- Marginal costs from fitted function
- Quantity and frequency of water market transfers by source

Summary data for least-cost solution
- When comparing alternative to base
    - Change in total costs and losses
    - Incremental SWP/CVP supply available for use or carryover storage
        - Hydrologic period average
        - Dry year average
    - Incremental unused SWP/CVP supply
        - Hydrologic period average
        - Dry year average
- Total costs and losses
- Forgone use costs and losses
- Fixed options cost
- Fixed option use
- Carryover option use
- Carryover option use
- Regional Operations cost
- Forgone use during 90/91drought period
- Total and average cost of water market transfers
- Supply from water market transfers from all sources by source
- Cost of water market transfers by source
- Water market transfer value

Data for the least-cost solution by year
- Supply
- Carryover storage by location
- Regional carryover storage use
- Contingency conservation
- Base and interruptible program use
- Water available from all water market sources for transfer
- Water market supply transferred from all sources
- Cost of water market transfers
- Forgone use quantity
- Percent shortage
- Forgone use losses
- Unused SWP supply
- Regional system operations costs

Data for the least-cost solution by water year type average
- Supply
- Regional carryover storage use
- Water market transfer supply
- Incremental SWP delivery
- Incremental CVP delivery
- Forgone use
- Forgone use losses
- Cost of water market transfers

Data for the least-cost solution for the use of regional water management options is also available in graphical form (this data is also available for the hydrologic reliability solution criteria):

Determination of least-cost point for regional water management option use
- Sequence of net costs and losses from forgone use and water market transfer purchase costs
- Sequence of regional water management option costs
- Sequence of total costs
  - Fitted polynomial smoothing function curve
  - Least cost point
  - Point at which hydrologic reliability criteria are met

Hydrologic reliability exceedence curve

Trace of yearly regional water management operations
- Supply
- Unused SWP supply
- Carryover operations
- Water market transfers
- Contingency conservation
- Forgone base and interruptible program use

Carryover Storage Augmentation Option. LCPSIM offers a limited ability to augment carryover storage capacity as an option. Only one existing carryover storage operation can be selected to be augmented. The augmentation assumes that annual put and take capacities are increased in proportion to the size of the augmentation. Information on which carryover storage operation is to be augmented and the cost of adding storage capacity to that operation is entered along with the data entered for the other regional management options. Shown in Figure 15 is the overall least-cost solution for the analysis of augmenting regional carryover storage capacity (triangle). Figure 16 depicts the LCPSIM logic used for the analysis of carryover storage capacity augmentation. Additional data applicable to the analysis of carryover storage capacity augmentation are available as results.

Figure 15. Overall Least-Cost Solution for Carryover Storage Augmentation

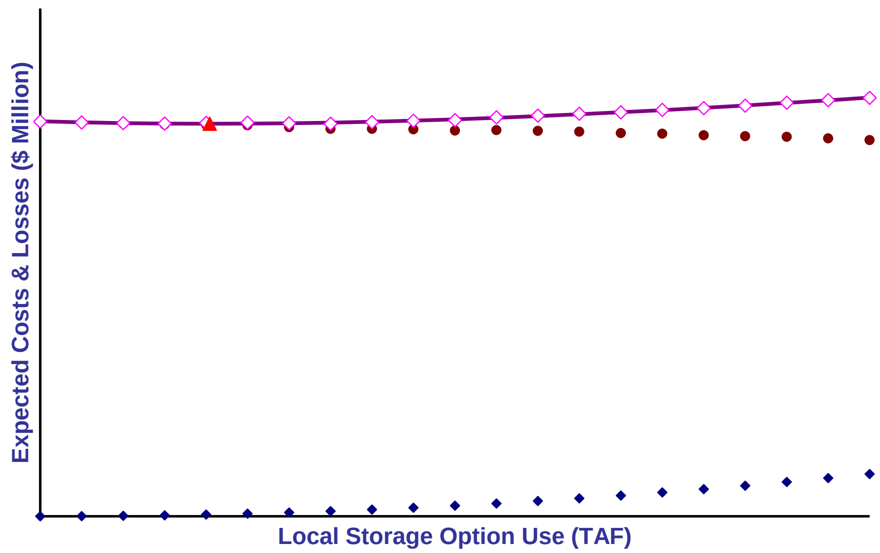
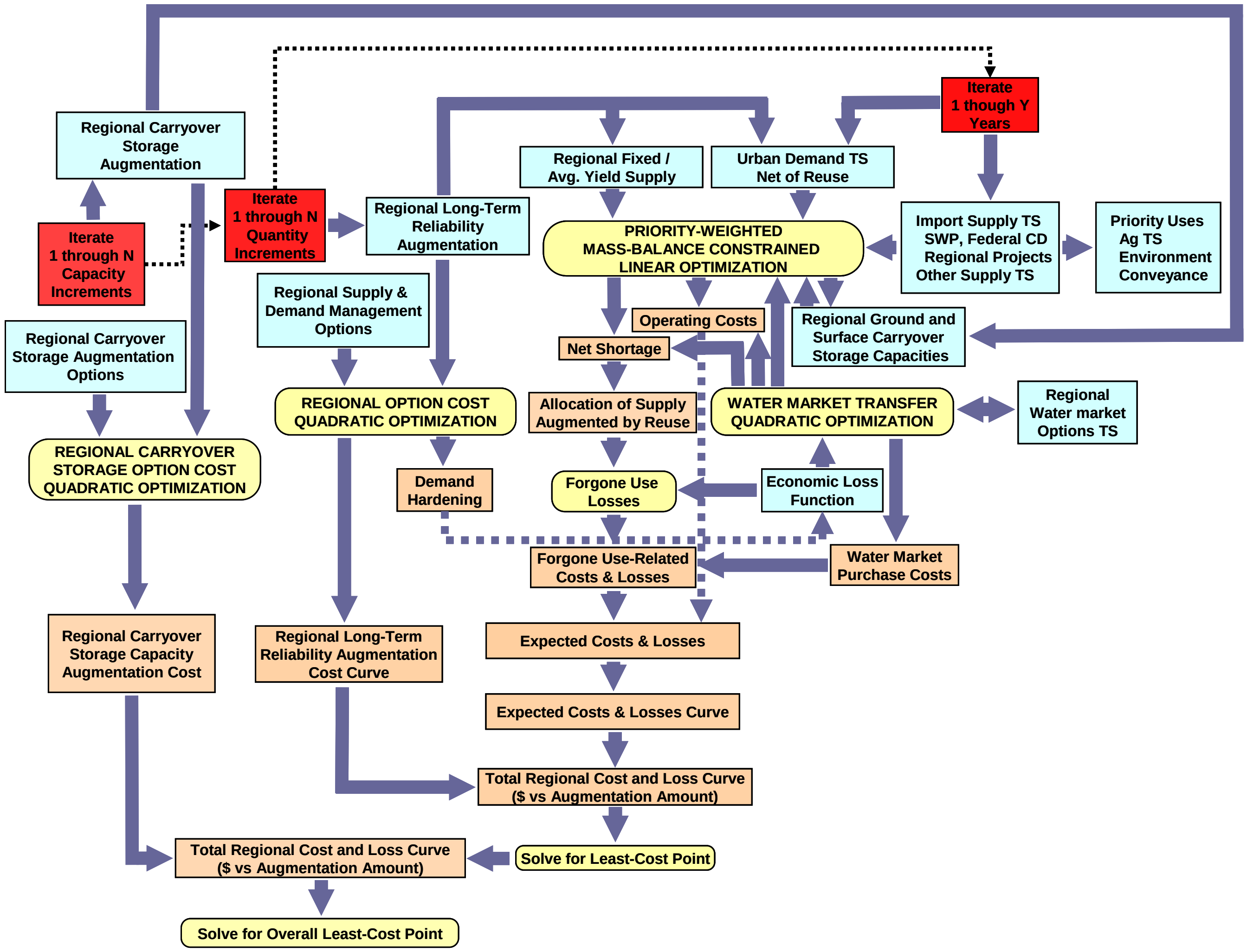


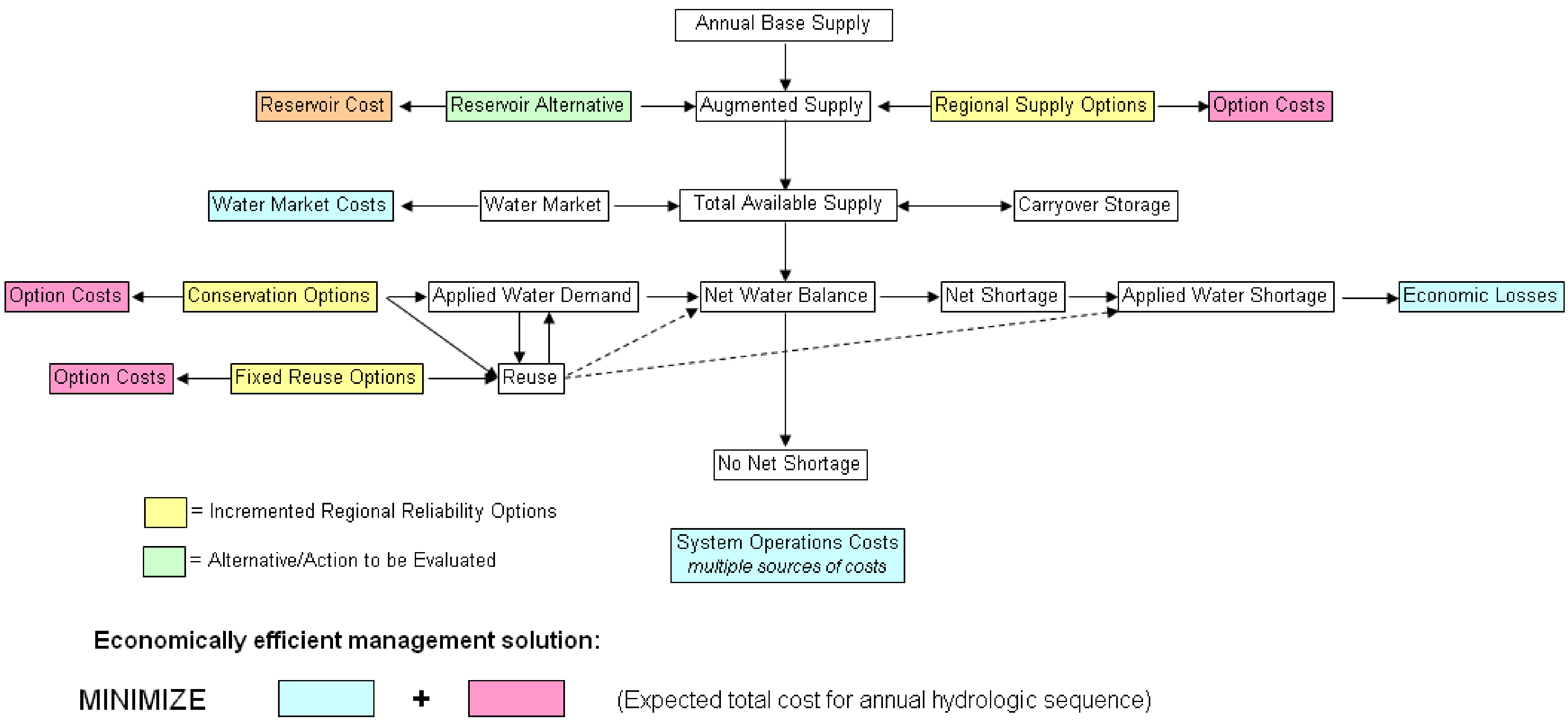
Figure 16. Analysis of Carryover Storage Augmentation



Regional Cost-Benefit Analysis with LCPSIM

LCPSIM was developed to do regional cost-benefit analyses for proposed SWP storage facilities. Depicted in Figure 17 is the analysis strategy used to determine project benefits for comparison with project costs. Regional reliability management options are shown either as supply (e.g., desalting), conservation (e.g., low-flow toilets), or fixed reuse (e.g., recycling) options. LCPSIM is used to find the economically efficient (i.e., least-cost) management strategy for the reservoir alternatives being considered, including the no-project alternative. The reduction in total regional costs when each with-project alternative is compared to the no-project alternative is the regional economic benefits ascribable to that alternative. These benefits can then be used in a separable costs, remaining benefits (SC-RB) cost allocation analysis to determine the project costs allocable to that region. Comparing the allocated costs to the regional benefits for each alternative provides the B-C ratio or the net benefits for that alternative, as appropriate.

Figure 17. Framework for Benefit-Cost Analysis Using LCPSIM



Regional Option Cost Minimization Analysis with LCPSIM

LCPSIM can also be used to determine if the use of regional options alone can provide at least the same hydrologic reliability or shortage event-related cost and loss reduction benefits as a base scenario. In this case, the “with project” water supply condition would be used as the base scenario and the “without project” condition used as the alternative scenario.

For this type of analysis, the solution is least-cost only in the sense that the cost of regional option use is minimized. For the hydrologic reliability criterion, regional options are added to the alternative scenario to the point where the hydrologic exceedence curve of the base scenario is dominated (i.e., no point on the alternative curve falls below the base curve). For the economic reliability criterion, the same dominance strategy is used for an economic cost/loss reliability curve. For the expected value criterion, regional options are added to the base scenario to the point where the expected value of shortage event-related costs and losses is equal to or lower than in the base scenario.

LCPSIM Limitations

The LCPSIM is not appropriate for individual water agency management decisions because of the simplifying assumptions it makes about system operations. These assumptions were made in order to keep the input data requirements and the complexity of the model logic at a level commensurate with the requirements of the regional level of the DWR studies for which it was designed.

Economic benefits are in LCPSIM computed at specifically identified demand levels (e.g., Year 2020 level.) The model thereby conforms to CALSIM hydrologic output which is generated for specific study year levels and is tied to target deliveries and upstream depletions tied to those levels, rather than over a period of time. Because the economic life of the alternatives to be evaluated can be up to fifty years or more, benefit estimation will be biased if only a single study year level is used and if, for the study period, the LCPSIM results are not reasonably equivalent to the annualized sum of the discounted benefits prior to the year level used added to the discounted benefits subsequent to the year level used. Running the LCPSIM for multiple year levels over the study period will reduce the magnitude of this bias but require large amounts of data.

The LCPSIM uses regional operations studies for local imported supplies to obtain annual delivery information. Regional water supply sources that are not modeled on a year-to-year basis in the LCPSIM are assumed to be continually at their average year values. This simplifying assumption can bias the results by not capturing the costs and losses which can arise when deliveries from these regional supplies and the explicitly modeled imported supply systems are reduced concurrently and by not capturing the benefits of augmenting carryover storage when deliveries both sources are at their highest levels concurrently.

The determination of reliability benefits is done in the LCPSIM on the basis of a risk-neutral view of risk management. Risk-averse management (risk minimization) by regional agencies–which has been the predominant mode–would result in the justification of more costly water management measures than under the risk-neutral assumption. Also, the LCPSIM will not be as useful for water managers who base reliability investment decisions on the hydrologic (e.g., percentage of target delivery met) rather than economic performance of their system over a specified drought sequence (e.g., 1928 to 1934.) The loss function used could, however, be modified to more or less replicate this strategy.

LCPSIM assumes that the regions being evaluated have the facilities and institutional agreements in place to move water as needed to minimize the impact of shortage events. For this reason, the use of LCPSIM on a regional basis is only appropriate for regions where this assumption is likely to be generally true within the time frame being modeled: the South San Francisco Bay Area and South Coast Region. It can also be appropriate when economic inefficiency arises from the lack of physical facilities and institutional agreements due to regional policy choices and it has been determined that this inefficiency should not be a factor in determining a statewide interest in a proposed water supply project, for example.

If, in general, interconnections and joint management do not realistically characterize a region, the calculation of the benefits of additional reliability may be biased. For example, if the ability of the region to mitigate the costs of forgone use with regional water allocation programs is significantly less than assumed in LCPSIM, a higher value may be assigned to useable deliveries from a reservoir supply alternative in a particular subregion but the amount of the supply actually useable may be reduced (e.g., the reservoir may be relegated to more of a peaking supply because the greater use of constant “yield” conservation and recycling measures may be justified for that subregion, reducing the usability of reservoir deliveries in wetter years.) In any case, to extent that region-wide shortage contingency water allocation plans are expected to be put in place in the future, this bias will be reduced.

LCPSIM is designed to use base urban quantity demanded as estimated by the IWR-MAIN or similar model. The quantity demanded reflects the expected adoption of conservation measures, including those specified in Urban Best Management Practices MOU, and incorporates water price elasticity effects on use. These base urban quantity demanded amounts are not reduced further in LCPSIM in response to the higher urban user water prices which can be anticipated as regions use water pricing as a means of recovering the cost of increasing reliability. In accordance with the economic efficiency objective, quantity demanded is reduced in LCPSIM based on the marginal cost of alternatives to that reduction, however. If the water pricing strategy adopted by local agencies to recover costs reduces quantity demanded differently than the reduction logic in LCPSIM predicts, the model results will be biased.

The total cost/loss points generated by the LCPSIM simulation as the model responds to added increments of regional water management option use are intended to plot out a cost/loss response path. This point path is mathematically converted to a continuous function by using polynomial smoothing. This function is then solved analytically to identify the least-cost solution consisting of a level of use of regional water management options and the total costs and losses associated with that level of use.

LCPSIM is set up to be a “best estimate” model. It is not intended to provide confidence intervals for statistical hypothesis purposes.

As well as relying on a simplified representation of the physical configuration of regional water management system, LCPSIM is based on determining a “least-cost” solution from the perspective of

The order of the polynomial smoothing function can be set by the model user based on the user’s view of the trade-off between minimizing the rate of change in the slope of the function (i.e., a smoother function) and a function which is less smooth but more closely follows the path of the points (i.e., maximizes the goodness of fit). If the LCPSIM user feels that, on average, the real world operations would be unlikely to duplicate the results of the threshold-based operating criteria incorporated in the model, then fitting the model-generated points too closely would be likely to bias the model results.

Selecting the starting and ending regional option use points for the simulation can also affect the results of smoothing. Adjusting the range of option availability is another trade-off that the user may make to exclude or include information that may or may not be useful for identifying an optimal solution point based on the user’s judgment.

If Excel® is installed, selecting **View Operations Trace** in the LCPSIM **Run/View Menu** will also make available a spreadsheet smoothing analysis utility which can be used to select the order of the polynomial smoothing function and the range of option use results to smooth which the analyst feels best represents the model output. These parameters can then be used to rerun LCPSIM to generate new results files.

statewide economic efficiency for the purpose of identifying the level of statewide interest in the commitment of resources to a proposed project or program. Local planning decisions are likely to be influenced by local cost effectiveness and political concerns as well as additional factors of importance to regional water agency managers and water users that are not necessarily related to the LCPSIM objective.

Because LCPSIM is used to optimize regional economic efficiency from a statewide perspective, shortage event-related cost and loss values, operations cost values, as well as the short-term and long-term management option cost values are lifecycle costs whenever possible. For example, conservation costs are adjusted for end user energy savings and water supply costs include the cost of wastewater treatment. For this reason, LCPSIM results may not reflect decisions made by water agencies based on their perspective on costs. Also, water users may or may not use information on energy savings when they make decisions on adopting conservation measures.

Based on the context in which the results will be used, LCPSIM results should be compared to local agency water management plans to help determine whether it would appropriate – or feasible – to modify model to be more representative of the region from the local management perspective.

References

Personal communication with Brandon Goshi, Metropolitan Water District of Southern California, December 2004

Randall, D., Cleland, L., Kuehne, C. S., Link, G. W., and Sheer, D. P. “Water Supply Planning Simulation Model Using Mixed-Integer Linear Programming ‘Engine.’”, Journal of Water Resources Planning and Management, March/April 1997.

SWRCB Bay-Delta Hearings, State Water Contractors Exhibit 51, “Economic Value of Reliable Water Supplies”, June 1987

Barakat & Chamberlin, Inc., “The Value of Water Supply Reliability: Results of a Contingent Valuation Survey of Residential Customers”, California Urban Water Agencies, August 1994

Appendix A

LCPSIM Input and Output Data

The information displayed in these example input data files is for the South Coast Region for a 2030 level of analysis. These numbers are for illustrative purposes only. The format of the files is ASCII and the data is stored without the row headings.

Table A-1. Example Parameter File (*.prm)

Parameter	Value	Notes
1. Total conveyance capacity avail for Central Valley imports (TAF)	3,000.0	
2. Base average non-time series regional water supply (TAF)	1,497.1	
3. Avg year applied Ag water use (TAF)	629.0	
4. Reuse of Ag applied water (TAF)	62.9	
5. Avg year Ag & M&I conveyance & other applied water use (TAF)	53.0	
6. Reuse of Ag & M&I conveyance & other applied water (TAF)	0.0	
7. Avg year applied M&I water use after base conservation (TAF)	4,886.0	
8. Base long-term M&I conservation of applied water (TAF)	510.0	
9. Interruptible program applied use (TAF)	16.2	
10. Total reuse of M&I applied water (TAF)	721.0	
11. Supply-dependent reuse of interior M&I applied water (TAF)	91.4	1
12. Supply-dependent reuse of exterior M&I applied water (TAF)	121.4	
13. Interior conservation effectiveness (%)	97.1%	2
14. Exterior conservation effectiveness (%)	65.7%	
15. Cost of reuse of deep percolation ($/AF)	$38.10	3
16. Share of exterior use unaffected by ETAW (%)	35.0%	4
17. Federal service contract aqueduct capacity (TAF)	1,200.0	
18. Table A amount affecting federal svc aqueduct capacity (TAF)	187.1	5
19. Cost of federal svc aqueduct conveyance ($/AF)	$70.00	
20. Cost of federal svc aqueduct use to GW bank ($/AF)	$48.00	
21. Cost of SWP aqueduct use to region ($/AF)	$150.00	
22. Cost of SWP aqueduct use to GW bank ($/AF)	$22.00	
23. Value of interruptible program delivery ($/AF)	$241.00	6
24. Fraction of interruptible supply treated (%)	46.0%	
25. Fraction of single-family residential use that is interior (%)	67.1%	
26. Fraction of multi-family residential use that is interior (%)	81.6%	
27. Fraction of commercial use that is interior (%)	76.5%	
28. Fraction of industrial use that is interior (%)	82.5%	
29. Fraction of wastewater centrally treated (%)	97.0%	7
30. Cost of M&I potable water treatment and delivery ($/AF)	$114.00	
31. Cost of M&I wastewater treatment ($/AF)	$47.00	
32. Cost of M&I delivery ($/AF)	$23.00	
33. Multi-family residential customer size (%)	16.3%	8
34. Industrial customer size (% of total use)	3.8%	
35. Commercial customer size (% of total use)	31.0%	
36. Landscape customer size (% of total use)	4.1%	
37. Cost for publicity campaign ($/capita)	$0.25	
38. Use reduction with contingency conservation campaign (%)	5.0%	

Table A-1. Example Parameter File (Cont.)

Parameter	Value	Notes
39. Use reduction with contingency conservation campaign (%)	5.0%	
40. Take call ratio for using contingency conservation (%)	100.0%	9
41. Capacity use ratio for using contingency conservation (%)	20.0%	
42. Interior use cut ratio (%)	64.0%	10
43. Multi-family residential customer cut ratio (%)	60.0%	11
44. Industrial customer cut ratio (%)	25.0%	
45. Commercial customer cut ratio (%)	55.0%	
46. Landscape customer cut ratio (%)	160.0%	
47. Threshold for shortage allocation (%)	95.0%	12
48. Threshold to adjust loss for proximate shortages (%)	0.0%	13
49. Loss value adjustment factor for consecutive shortages (%)	0.0%	
50. Inverse power function exponent for loss value adjustment	1.0	
51. Zero point for contingency reduction of interruptible deliv (%)	35.0%	14
52. Shortage contingency water transfer threshold (%)	100.0%	15
53. Depleted carryover storage water transfer threshold (%)	80.0%	16
54. Cost for rationing program ($/capita)	$0.50	
55. Rationing program threshold (%)	80.0%	
56. Regional urban population (thousands)	23,827.0	
57. Price for CPED function ($)	$1,074.00	
58. Elasticity for CPED function	-0.064	
59. Demand hardening adjustment factor (%)	50.0%	17
60. Hedging point (%)	60.0%	18
61. Hedging call/storage factor	0.25	
62. Hedging storage/capacity factor	0.25	
63. Reserve reservoir storage hedging: 0: None, 1: Hedged	0	19
64. Regional reservoir hedging: 0: None, 1: Hedged	0	
65. Regional GW hedging: 0: None, 1: Hedged	0	
66. Regional GW bank hedging: 0: None, 1: Hedged	0	
67. SWP aqueduct GW bank hedging: 0: None, 1: Hedged	0	
68. Federal svc aqueduct GW bank hedging: 0: None, 1: Hedged	0	
69. Reserve storage management: 0: None, 1: Managed	0	20

Table A-1. Example Parameter File (Cont.)

Notes:

[1] Reuse which does not arise from a fixed source (i.e., recycling).

[2] Ratio between the reduction in required regional supply and the quantity of applied water conserved.

[3] Used to reduce the effective cost of conservation to account for any resulting reduction in regional deep percolation.

[4] Share of exterior use which is assumed to be fixed rather than vary directly with ETAW.

[5] Federal service contract aqueduct capacity required for full SWP Table A exchange deliveries. Used with Table A percentage delivery time series file to model residual capacity in the Colorado River Aqueduct for the South Coast Region.

[6] Assumed to the the price paid by users of that supply.

[7] Excludes wastewater going to septic tanks.

[8] Size of customer category for which use reduction will be held to the respective cut ratio compared to residential users.

[9] Used for triggering contingency conservation over and above a mass balance requirement for its use. When (1 - capacity use ratio) / (1 - capacity use ratio limit) + (take call ratio) / (take call ratio limit) exceeds 1, contingency conservation is triggered (unrestricted transfers, if available, are used in the call calculation for this purpose).

[10] Ratio at which interior urban use will be cut relative to total cut in urban use.

[11] Ratios with which users in the respective customer categories will be cut relative to residential users.

[12] Below this point, all users will experience the same percentage reduction.

[13] Proximate losses are increased by a loss adjustment factor to account for residual damage effects:
(consecutive shortage adjustment adjustment factor) / (year of subsequent shortage ^ power function exponent)
No loss adjustment is made for loss event years more than two years apart (year of subsequent shortage = 3).

[14] At this point and above, interruptible deliveres are not made.

[15] Used if a regional shortage has to exceed a specified percentage before transfers from this source type are allowed.

[16] The ratio of supply in carryover storage to carryover storage take capacity at which transfers to replenish carryover storage are triggered.

[17] The factor by which use reductions through conservation options as a percentage of initial use are used to adjust shortage size (i.e., effective shortage).

[18] Parameters used for hedging logic: if storage is less than hedging point then percent of storage made available is
1 - (call/storage factor) * (call/storage ratio) * (storage/capacity ratio) ^ (- storage/capacity factor).

[19] Storage categories included for hedging purposes (hedging is applied to the total storage amount).

[20] When managed is selected, top priority is given to refill for this type of storage, triggering conservation if required.

Table A-2. Example Regional Water Management Options File (*.opt)

Source[1]	Amount Avail (TAF)	Cost (Base) ($/AF)	Cost (Incremental) ($/TAF)	Change in Net Use[2] (% of Applied)	Source[3] (Type)	Description (AlphaNumeric)
1	16.1	$513	$1.04	97.1%	7	Indoor Conservation Level I
2	14.9	$811	$9.46	97.1%	7	Indoor Conservation Level II
3	6.6	$1,490	$61.81	97.1%	7	Indoor Conservation Level III
4	248.0	$1,900	$0.00	97.1%	7	Indoor Conservation Level IV
5	99.0	$905	$0.00	66.8%	8	Outdoor Conservation Level I
6	100.0	$1,000	$0.00	66.8%	8	Outdoor Conservation Level II
7	50.0	$1,500	$0.00	66.8%	8	Outdoor Conservation Level III
8	50.0	$2,000	$0.00	66.8%	8	Outdoor Conservation Level IV
9	64.0	$723	$2.50	100.0%	2	Water Recycling Level I
10	212.0	$1,093	$2.10	100.0%	2	Water Recycling Level II
11	697.4	$1,539	$1.40	100.0%	2	Water Recycling Level III
12	171.5	$1,743	$1.30	100.0%	5	Ocean Water Desalting Level I
13	108.5	$2,149	$5.60	100.0%	5	Ocean Water Desalting Level II

Notes:

[1]Up to 20 supply/conservation and 20 carryover options can be entered (only one carryover storage operation can be augmented, however, with put and take limits adjusted in proportion to the initial put/capacity and take/capacity ratios)

[2]Ratio between the applied water conserved and reduction in required regional supply (i.e., net use). Conservation can reduce surface runoff and/or deep percolation, both of which can be sources of applied water within a region. For this reason, an acre-foot of applied water reduction by conservation can result in a reduction of less than of an acre-foot in the need for regional supplies.

[3]Used to identify as supply, reuse, conservation, or storage and to assign treatment and conveyance costs as well as for adjusting for demand hardening:

1: Recycling delivery into regional distribution system treatment plant
2: Recycling delivery into regional distribution system
3: Recycling delivery into own distribution system
4: Supply delivery into regional distribution system treatment plant
5: Supply delivery into regional distribution system
6: Supply delivery into own distribution system
7: Interior conservation
8: Exterior conservation
9: Distribution system conservation
> 10 : Class of carryover storage being augmented + 10

Table A-3. Example Carryover Storage Operations File (*.stg)

Operation[1]	Capacity (TAF)	Init. Fill	Rech. Eff.	Put Limit (TAF)	Put Cost	Put Prty[2]	Take Limit[3] (TAF)	Take Cost	Take Prty[2]	Class[4]	Type[5]	Opr. Rule[6]	Description
1	220.0	100%	100%	220.0	$0	2.0	220.0	$0	6.0	1	1	0	Reserve Reservoir Operations
2	600.0	50%	100%	600.0	$0	1.0	287.0	$0	3.0	2	1	0	In-Region Reservoir Operations
3	195.0	50%	100%	56.0	$65	3.0	75.0	$65	3.0	3	1	0	IRP GW Program
4	267.0	50%	90%	66.8	$0	3.0	89.0	$81	5.0	3	2	0	Prop 13 & Raymond Basin GW
5	210.0	50%	90%	55.0	$94	3.0	70.0	$94	5.0	4	1	0	North Los Posas Banking
6	75.0	50%	90%	20.0	$0	3.0	50.0	$79	5.0	4	1	0	San Bernardino Banking
7	800.0	50%	90%	150.0	$0	6.0	150.0	$34	2.0	5	4	0	Colo R. Aq. GW Banking Operations
8	310.0	50%	90%	155.5	$81	5.0	125.0	$44	4.0	6	6	4	Kern-Delta WD & North Kern WSD
9	350.0	50%	90%	31.7	$35	5.0	31.5	$33	4.0	6	6	1	Semitropic WSD
10	75.0	50%	90%	75.0	$91	5.0	56.0	$61	4.0	6	6	2	Mojave WSD
11	250.0	50%	90%	100.0	$62	5.0	75.0	$45	4.0	6	6	3	Arvin-Edison WSD
12	285.5	0%	100%	285.5	$0	4.0	285.5	$0	1.0	7	0	5	SWP Carryover Storage

Notes:

[1]LCPSIM code currently permits twenty storage operations to be entered.

[2]Highest priority = 1 (By default, LCPSIM uses dynamic priorities; these priorities may be used instead by selecting "Use Static Priorities" on the Main Screen).

[3]These limits can be used for take operations and are always used for calculating storage depletion for the purpose of making market transfers for recharge. If either a Type 1 or Type 2 operating rule is indicated, these limits are overidden by the rule parameters entered in the respective parameter files for take operations.

[4]Storage class ID:
- 1: Flexible reservoir storage
- 2: In-Region reservoir storage
- 3: In-Region GW storage
- 4: In-Region GW bank
- 5: Federal service contract aqueduct GW Bank
- 6: External SWP aqueduct GW bank
- 7: SWP reservoir carryover

[5]Used for conveyance and treatment costs for puts and takes:
- 1: SWP conveyance to region for puts
- 2: SWP conveyance to region and treatment costs for puts (spreading of treated water for GW recharge)
- 3: SWP conveyance to SWP aqueduct bank for puts, conveyance from SWP aqueduct bank to region for takes
- 4: SWP Conveyance to SWP East Branch aqueduct bank for Puts, conveyance from Delta for takes
- 5: Federal service aqueduct bank conveyance to bank for puts, conveyance from federal service aqueduct bank to region for takes
- 6: SWP conveyance to SWP bank for puts, conveyance from Delta for takes
- 7: SWP Conveyance to region for puts, federal service aqueduct conveyance for takes

[6]Type of operating rule:
- 1: Percentage Table A delivery take constraint - Semitropic WSD
- 2: Percentage Table A delivery take constraint - Moajve WA
- 3: Consecutive use take constraint - Arvin-Edison WSD
- 4: Direct SWP SJV GW bank augmentation
- 5: Generic SJV storage
- 6: SWP carryover

Table A-4: Example Water Transfers Market File (*.mkt)

Source[1]	Amount Avail[2] (TAF)	Cost (Base) ($/AF)	Cost (Incremental) ($/TAF)	Conveyance[3] (Type)	Max Interval[4] (% of avail)	Max Sequential[5] (% of avail)	Deliv. Adj.[6] (%)	Description (AlphaNumeric)
1	650	$150	$0.00	4	1000%	200%	100%	Colo Riv Transfers
2	5,000	$160	$0.00	2	1000%	200%	100%	SV Ag Transfers
3	5,000	$268	$0.00	3	1000%	200%	100%	SJV Ag Transfers

Notes:

[1]Multiple transfer sources can be entered (up to 15)

[2]Available at source; overridden when time series transfer quantity files are found by LCPSIM. Time series transfer quantities are assumed either to be adjusted for losses or to be at the source (not adjusted for losses), based on the availability of time series delivery adjustment files (see Note 6, below).

[3]Used for capacity and operational constraints and conveyance cost calculations:
1: No transfer constraint or transfer costs
2: Sacramento Valley transfers
3: San Joaquin Valley Transfers
4: Federal service contract conveyance transfers

[4]Maximum amount that can be transferred over any ten year period

[5]Maximum that can be transferred in any two consecutive years
(If Max Interval is 1000% and Max Sequential is 200% then transfers are unrestricted)

[6]Adjustment for conveyance losses (e.g., Delta carrage water requirement); overridden when time series delivery adjustment files are found by LCPSIM. If found, time series transfer quantities are assumed be adjusted for losses, otherwise, they are assumed to be at source (unadjusted).

Table A-5. Example Water Market Year-Type Cost File (*.cst)

Type/Value	SV Base Cost ($/AF)	SV Inc Cost ($/TAF)	SJV Base Cost ($/AF)	SJV Inc Cost ($/TAF)
Wet	$135	$0.00	$182	$0.00
Above Normal	$135	$0.00	$196	$0.00
Below Normal	$135	$0.00	$206	$0.00
Dry	$151	$0.00	$281	$0.00
Critical	$175	$0.00	$281	$0.00
Driest Yrs Dry	$182	$0.00	$338	$0.00
Driest Yrs Critical	$210	$0.00	$338	$0.00

Note: Reflects higher cost to Sacramento Valley and San Joaquin Valley agricuture of forgoing supplies in drier years

Table A-6. Example Hydrologic Reliability Criteria File (*.hrc)

Criteria Step[1]	Shortage[2] (%)	Freq of Exceedence[3] (%)
1	15%	100%
2	10%	90%
3	0%	80%

Notes:

[1]Can be up to four steps

[2]Shortage threshold

[3]Maximum frequency with which a shortage exceeding the threshold occurs

Table A-7. Example Polynomial Loss Function File (*.ply)

Coeff #	Coefficient[1]
1	774.7503972
2	25154.31596
3	-16396.5462
4	-3527.78814

Notes:

[1]Coefficients of loss function polynomial (can be up to a degree 3 as is the example)

Table A-8. Example Percentage Delivery Constrained Take Rule File (*.pdc)

Rule Parameter	Rule 1	Rule 2	Notes
Table A Allotment (TAF)[1]	155	75.8	1
Reserved Table A (TAF[2]	22	19.8	2
Share of Bank (%)[3]	0.35	1	3
Base Take Avail (TAF)[4]	31.5	0	4

Notes:

[1]SWP contract amount held by the agency operating the bank

[2]Amount of SWP contract quantity reserved for local use by the agency operating the bank

[3]Region's share of total bank capacity

[4]Guaranteed minimum take

Example: The take limit for MWDSC from the Semitropic WSD bank is equal to the bank's pumpback capacity (Base Take Avail) plus the product of MWDSC's percentage share of the bank and Semitropic's SWP Contract Table A delivery after subtracting Semitropic's reserved amount of that allocation: Base Take Avail + Share of Bank * ((Table A Allotment * Percentage of Table A Delivered) - Reserved Table A)

Table A-9. Example Consecutive Take Constrained Take Rule File (*.ctc)

Year No.[1]	Avaliable[2]
1	100%
2	75%
3	70%
4	60%
5	40%
6	0%

Notes:

[1]Consecutive take sequence year number

[2]Percentage of unconstrained take available

LCPSIM Time Series Input Data Files

The following table contains a list of the hydrologic sequence time series data files used by the LCPSIM and the file naming conventions expected by the model. The base files are vectors (single columns) while the scenario files can be matrices with the columns representing different scenarios.

Table A-10. Time Series Data Files

File Type	Description	Data Source	File Naming Convention	
			Base Case	Scenario
Study ID	CALSIM study identification header text	Study name	*basefileid*.sid[1]	*scnfileid*.sid[2]
SWP Table A Delivery	CALSIM SWP Table A contractor deliveries	CALSIM II	*basefileid*.tba[1]	*scnfileid*.tba[2]
SWP Article 21 Delivery	CALSIM SWP Article 21 contractor deliveries	CALSIM II	*basefileid*.a21[1]	*scnfileid*.a21[2]
Federal Contract Delivery	Deliveries based on federal water service contracts (e.g., CALSIM CVP contractor deliveries)[3]	CALSIM II or regional model	*fcdbasefileid*.fcd[4]	*scnfileid*.fcd[2]
Other Variable Supply	Regional supply unaffected by study scenarios	Regional model	*ovsfileid*.ovs[4]	n/a[5]
Ag Applied Use Factor	Weighted variation in crop ETAW from average	SIMETAW model	*auffileid*.auf[4]	n/a[5]
External Urban Use Factor	Weighted variation in turfgrass ETAW from average	SIMETAW model	*euffileid*.euf[4]	n/a[5]
SWP GW Augmentation	CALSIM GW augmentation deliveries	CALSIM II	*basefileid*.exb[1]	*scnfileid*.exb[2]
Total Transfer Limit	CALSIM water market total transfer capacities (quantities at source)	CALSIM II	*basefileid*.tlm[1]	*scnfileid*.tlm[2]
SAC Transfer Limit	CALSIM Sacramento Valley water market transfer delivery capacities net of losses	CALSIM II	*basefileid*.tsv[1]	*scnfileid*.tsv[2]
SJV Transfer Limit	CALSIM San Joaquin Valley water market transfer delivery capacities net of losses	CALSIM II	*basefileid*.tsj[1]	*scnfileid*.tsj[2]
SAC Transfer Factor	CALSIM Sacramento Valley water market transfer loss factors	CALSIM II	*basefileid*.fsv[1]	*scnfileid*.fsv[2]
SJV Transfer Factor	CALSIM San Joaquin Valley water market transfer loss factors	CALSIM II	*basefileid*.fsj[1]	*scnfileid*.fsj[2]
Table A Percentage	CALSIM SWP contractor deliveries as a percentage of Table A contract amounts	CALSIM II	*basefileid*.tap[1]	*scnfileid*.tap[2]
SWP Carryover Storage	Capacity for undelivered water to be stored by the SWP in San Luis Reservoir for delivery in the following year	CALSIM II	*basefileid*.slc[1]	*scnfileid*.slc[2]
Table A Turnbacks	SWP Table A deliveries assumed to be available due to inability to use them in another region	LCPSIM	*basefileid*.tat[1]	*scnfileid*.tat[2]
Article 21 Turnbacks	SWP Article 21 deliveries assumed to be available due to inability to use them in another region	LCPSIM	*basefileid*.a2t[1]	*scnfileid*.a2t[2]

Notes:

[1]These files must have the same primary file name (*basefileid*) and are required to be in the same directory and are loaded into LCPSIM when the Project File (*.prj) is opened.

[2]These files must have the same primary file name (*scnfileid*) and are required to be in the same directory. They are loaded when the SWP Scenario File is opened. If this directory is different than the base case file directory, the base case files and the scenario files can have the same primary file names.

[3]For the South Coast Region, exchange deliveries to the Desert Water Agency and the Coachella Valley Water District from MWDSC's allocation of Colorado River water to replace their SWP Table A water are not included in the federal water service contract delivery file; they are included in file of SWP deliveries to the South Coast Region (*.tba). Residual Colorado River Aqueduct capacity is modeled using a full Table A delivery value set in the main parameter file and the Table A percentage delivery file (*.tap).

[4]These files can be in different directories and have different primary file names; they must be selected from the "View/Change Project Data Files" window, however. These files are also loaded into LCPSIM when the project file (*.prj) is opened.

[5]No scenario files are used for this data, values are assumed to be the same as the base case for all scenarios.

DRAFT

Selected LCPSIM Output Data

Table A-11. Summary Results Output Format

Annual & Total Values / Scenario >	Description of Results (Values are for least-cost solution operations)
Avg Incremental Avail Supply (TAF)	Average annual incremental supply made available to the region by proposed project/program
Avg Incremental Deliv Supply (TAF)	Average annual amount of the incremental supply that the region can consumtively use or store
Avg Inc Dry Period Avail Sup (TAF)	Average annual incremental dry period supply made available to the region by proposed project/program
Avg Inc Deliv Dry Period Sup (TAF)	Average annual amount of the incremental dry period supply that the region can consumptively use or store
Expected Avoided Loss/Cost ($1,000)	Expected annual benefit of implementing proposed project/program
Expected Total Loss/Cost ($1,000)[1]	Expected annual total costs and losses associated with shortage and regional options use
Expected Shortage Loss/Cost ($1,000)	Expected annual shortage costs and losses
Annualized Option Cost ($1,000)	Regression fitted annualized costs of use of regional options
Supply/Reuse Augmentation (TAF)	Quantity of supply and/or reuse (e.g., recycling) augmentation due to use of regional options
Avg Net Demand Reduction (TAF)[2]	Average demand reduction from regional options adjusted for reuse (net effect on supply required to meet demand)
Avg Applied Demand Reduction (TAF)[2]	Average reduction of demand for applied water due to use of regional options
Marginal Option Cost ($/AF)	Annualized cost of next increment of supply/reuse/demand reduction from regional options
Carryover Option Use (TAF)[3]	Size of capacity added to regional carryover storage
Carryover Option Cost ($1,000)[3]	Annualized cost of adding to regional carryover storage
System Operations Cost ($1,000)	Cost of aqueduct conveyance, including wheeling of transfers and carryover storage, and other regional operations
Avg 1990-1991 Drought Shortage (%)	Average shortage for the 90/91 drought period
Total Water Market Deliveries (TAF)	Total quantity transferred over the hydrologic period
Avg Water Market Deliveries (TAF)	Average annual quantity transferred over the hyrdologic period
Total Water Market Cost ($1,000)	Total cost of transfers over the hyrdologic period
Avg Water Market Cost ($1,000)	Average annual cost of transfers
(Output for each of the five water year types plus dry period and # of years represented)	
***Water Year Type* Averages**	Name of water year type or period
SWP Deliveries (TAF)	Average SWP delivery
Fed Service Contract Deliveries (TAF)	Average federal service contract aqueduct delivery (e.g., CVP deliveries for the SF Bay Region)
Net Supply (TAF)	Average supply above current consumptive use
Unallocated SWP Deliveries (TAF)	Average incremental SWP delivery not allocable to current consumptive use or regional carryover storage
Puts to Storage (TAF)	Average puts to regional carryover storage facilities
Change in Storage (TAF)	Average change in regional carryover storage
Water Market Deliveries (TAF)	Average water market transfers
Net User Shortage (TAF)	Average user shortage after transfers
Total Loss/Cost ($1,000)	Average total costs and losses associated with shortage and regional options use
(Output for each regional option)	
Supply/Reuse/Conservation Option	Name of regional supply/reuse/conservation option as it appears in option file description
Supply / Reuse / Reduction (TAF)	Increase in supply, increase in reuse, or reduction in applied water use from regional option
Cost ($1,000)[3]	Unfitted annualized cost of regional option use
(Output for each regional option)	
Carryover Storage Option[3]	Name of regional carryover option as it appears in option file description
Use (TAF)	Size of capacity added to regional carryover storage
Cost ($1,000)[4]	Annualized cost of adding to regional carryover storage
(Output for each water market transfer source)	
Water Market Transfer Option	Name of water market transfer option as it appears in market file description
Number of Water Market Deliveries	Number of transfers during hyrdologic period
Total Deliveries (TAF)	Total quantity transferred during hyrdologic period
Cost ($1,000)	Total costs of transfers during hydrologic period
Average Quantity per Delivery (TAF)	Average quantity transferred per transfer event
Average Delivered Cost ($/AF)	Average unit cost of transfers
Frequency of Delivery	Frequency of transfer evens during hyrdologic period

Notes:

[1]Sum of "Expected Ann Shortage Cost/Loss", "Ann Regional Option Cost", "Ann Carryover Option Cost" (if used), and "Avg Ann Water Market Cost"

[2]Because the reduction due to exterior conservation depends on the quantity applied, which varies by year, the reported quantities are averages

[3]Will not be displayed if carryover storage options are not evaluated

[4]Sum of the costs for specific options will not equal "Ann Regional Option Cost" displayed above as the specific option costs represent the individual products of the unit costs of the options and the least-cost solution quantities identified; the "Ann Regional Option Cost" is a point on the cumulative option cost regression curve

[5]Sum of the costs for specific options will not equal "Ann Carryover Option Cost" displayed above as the specific option costs represent the individual products of the unit costs of the options and the least-cost solution quantities identified; the "Ann Carryover Option Cost" is a point on the cumulative option cost regression curve

DRAFT

Table A-12. Least-Cost Increment Results Output Format

Net Supply	Description of Results (Values are for least-cost solution operations) (Output for each year in the hydrologic sequence, for the five hydrologic year types, for the dry period, and for the average)
Net Supply	Supply available after netting out base long-term conservation-adjusted demand (negative value is deficit to be managed)
Aug Net Supply	Net adjustment to water balance from regional long-term supply, reuse, and conservation options implemented for least-cost solution
Resv Res Stg	Quantity of regional supply stored in reserve carryover storage
Rgnl Res Stg	Quantity of regional supply stored in within-region surface carryover storage
Rgnl GW Stg	Quantity of regional supply stored in within-region groundwater carryover storage
Rgnl GW Bank Stg	Quantity of regional supply stored in within-region groundwater banking storage
Cal Aq Bank Stg	Quantity of regional supply banked outside of region along the California Aqueduct in the San Joaquin Valley
Fed Svc Aq Bank Stg	Quantity of regional supply banked outside of region along the federal service contract aqueduct
Total Stg Change	Change in regional carryover storage from puts to storage (+) or withdrawls from storage to meet demand (-)
Cntgcy Consv	Conservation required to help balance supply and demand during shortage events or triggered by unfavorable carryover storage conditions
IPGM Use	Scheduled interruptible program cutback to help balance supply and demand during shortage events
Base Use	Cutback in use from quantity demanded over and above contingency conservation
Mkt Deliv Avail	Supply available for water market transfer based on conveyance capacity and third-party impact constraint rules
Mkt Deliv	Water market supply transferred to help meet demand remaining after contingency conservation during shortage events
Pct Shortage	Percentage cutback in use from quantity demanded during shortage events after water market transfers
Short Losses	Economic losses from cutback in use from quantity demanded during shortage events after water market transfers
Sum Trf Cost	Cost of water market transfers at their source
Unused Supply	SWP supply available but not delivered because of regional demand and carryover storage constraints
Sys Op Costs	Conveyance, distribution, treatment, and carryover storage operations costs
Src CV Mkt Trf	Total quantity of Central Valley water market transfers at the source of the transfer
Cap Use Ratio	Ratio between regional carryover storage supply and demand
Take Call Ratio	Ratio between regional storage take carryover capacity and demand
GW Stg Aug Avail	Transfer supply available for recharging depleted regional carryover storage
GW Stg Aug Used	Transfer supply used for recharging depleted regional carryover storage
Total Puts	Total quantity used for puts to regional carryover storage (can exceed supply stored because of efficiency assumptions)
SWP Carryover	Quantity of regional supply allocated to SWP carryover storage in San Luis
Semitropic	Quantity of regional supply banked outside of region in the Semitropic Water Storage District
Arvin-Edison	Quantity of regional supply banked outside of region in the Arvin-Edison Water Storage District
Kern-Delta	Quantity of regional supply banked outside of region in the Kern-Delta Water Storage District
SJV Bank	Quantity of the regional supply banked outside of region in a hypothetical San Joaquin Valley groundwater banking operation
Src SAC Mkt Trf	Quantity of Sacramento Valley water market transfers at the source of the transfer
Src SJV Mkt Trf	Quantity of San Joaquin Valley water market transfers at the source of the transfer
Src FCD Mkt Trf	Quantity of water market transfers at the source of the transfer that are conveyed by the federal service contract aqueduct
Net SAC Mkt Trf	Quantity of Sacramento Valley water market transfers delivered to the region
Net SJV Mkt Trf	Quantity of San Joaquin Valley water market transfers delivered to the region
Net FCD Mkt Trf	Quantity of water market transfers delivered to the region that are conveyed by the federal service contract aqueduct
Net Shrtg Mkt Trf	Total quantity of water market transfers delivered for use during shortage events
Net StgRec Mkt Trf	Total quantity of water market transfers delivered for augmenting depleted regional carryover storage

DRAFT

Appendix B

LCPSIM Interface Screens

The following figures depict selected screens in the LCPSIM:

Figure B-1. Main Screen

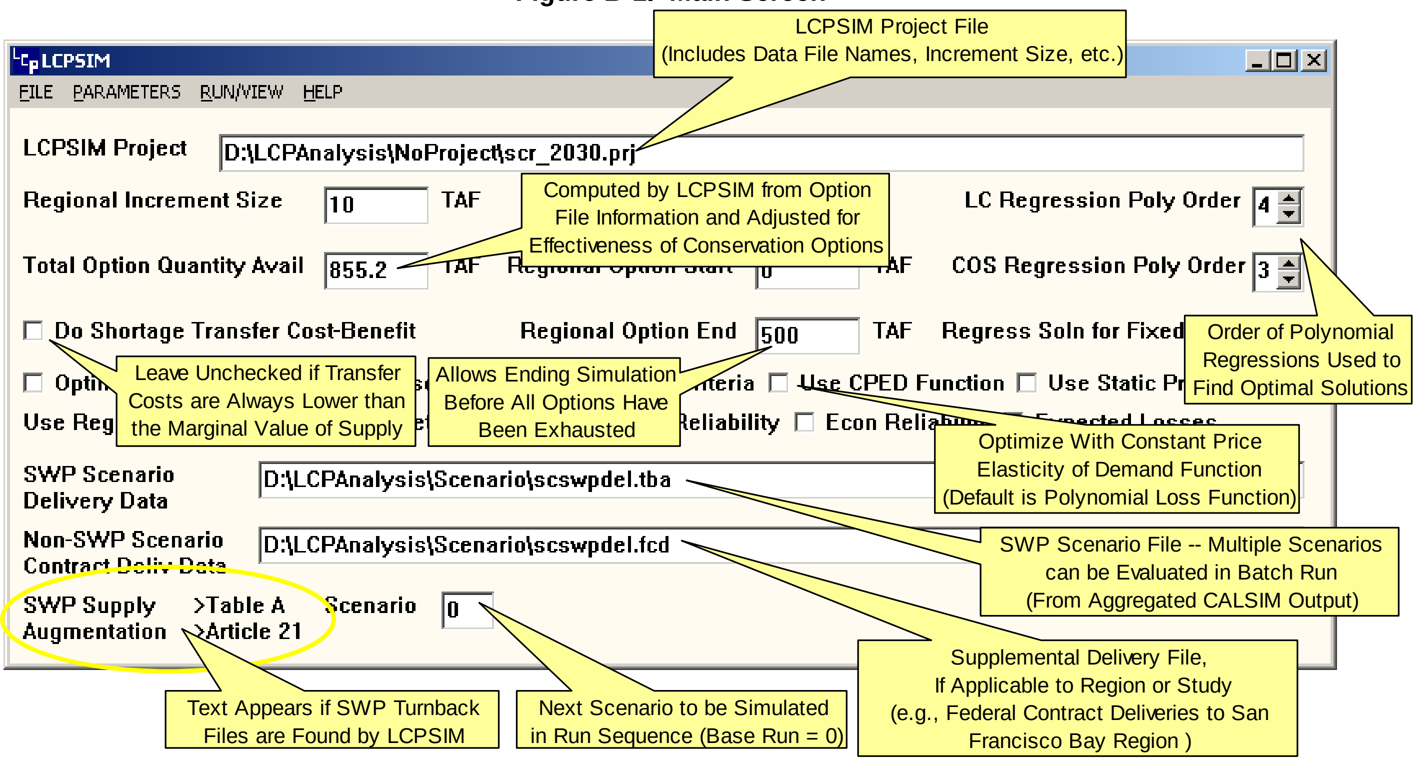


Figure B-2. Main Screen (Cont.)

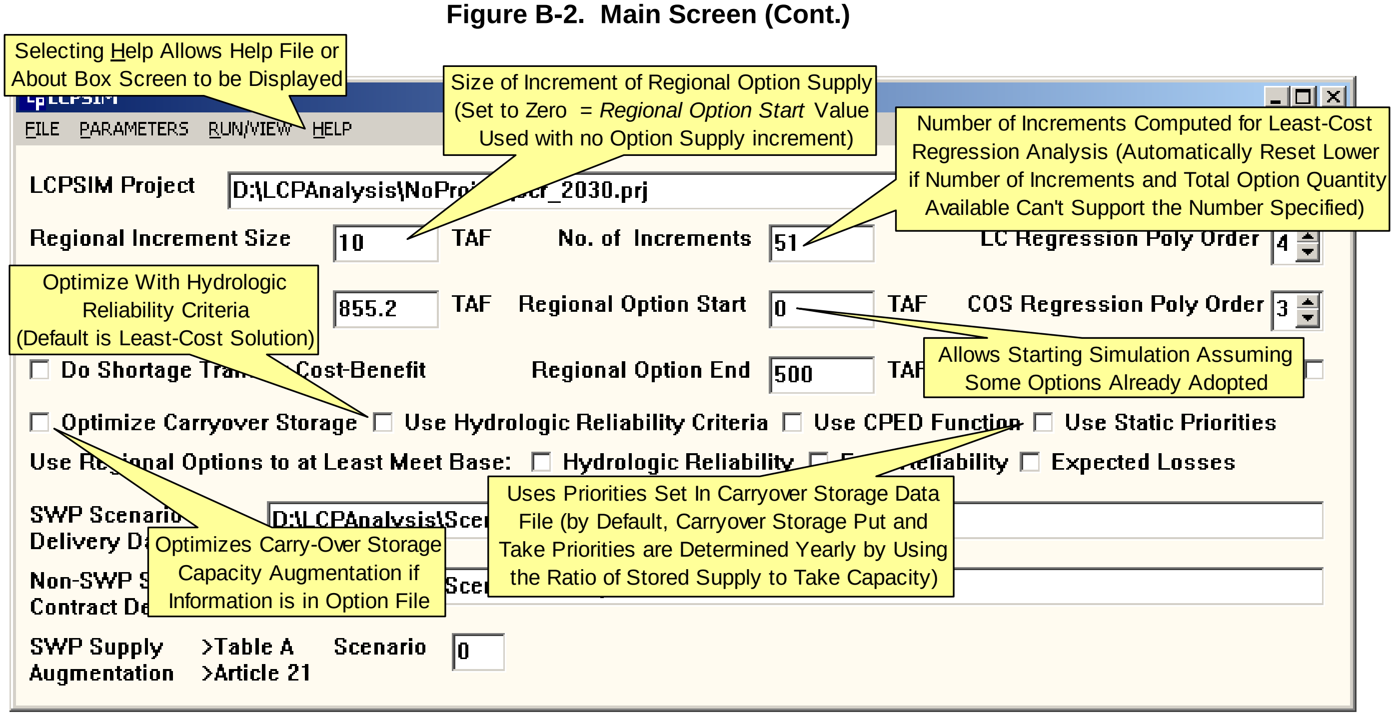


Figure B-3. Main Screen (Cont.)

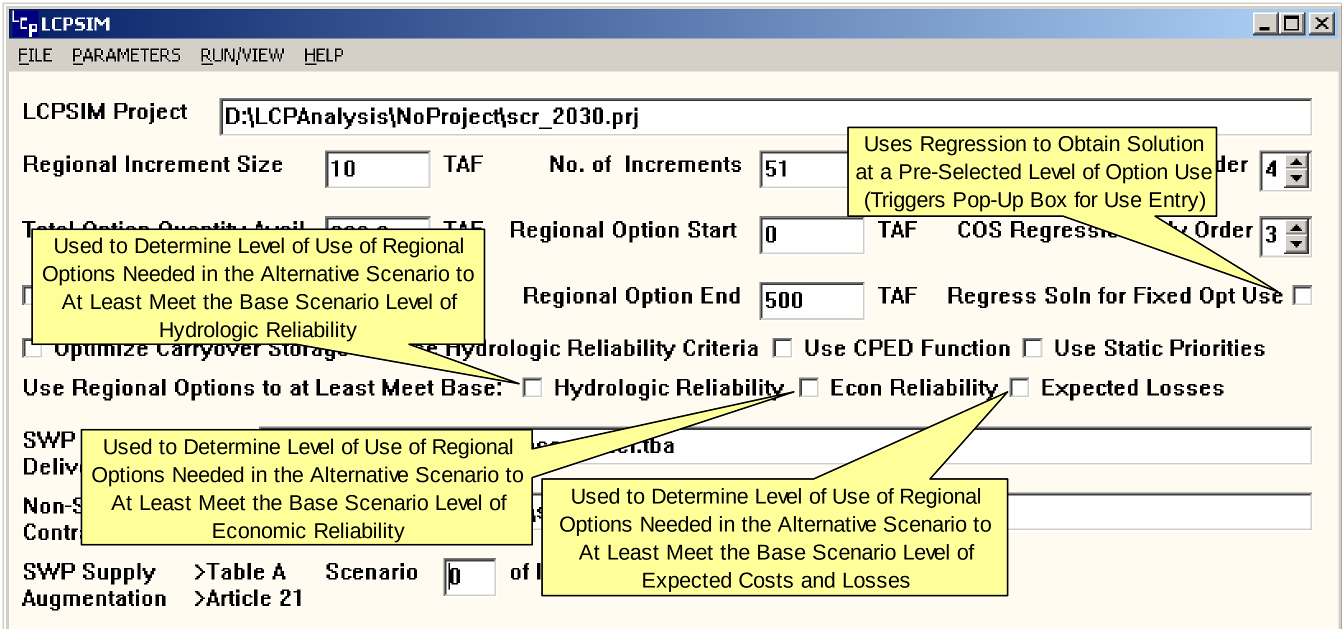


Figure B-4. File Menu

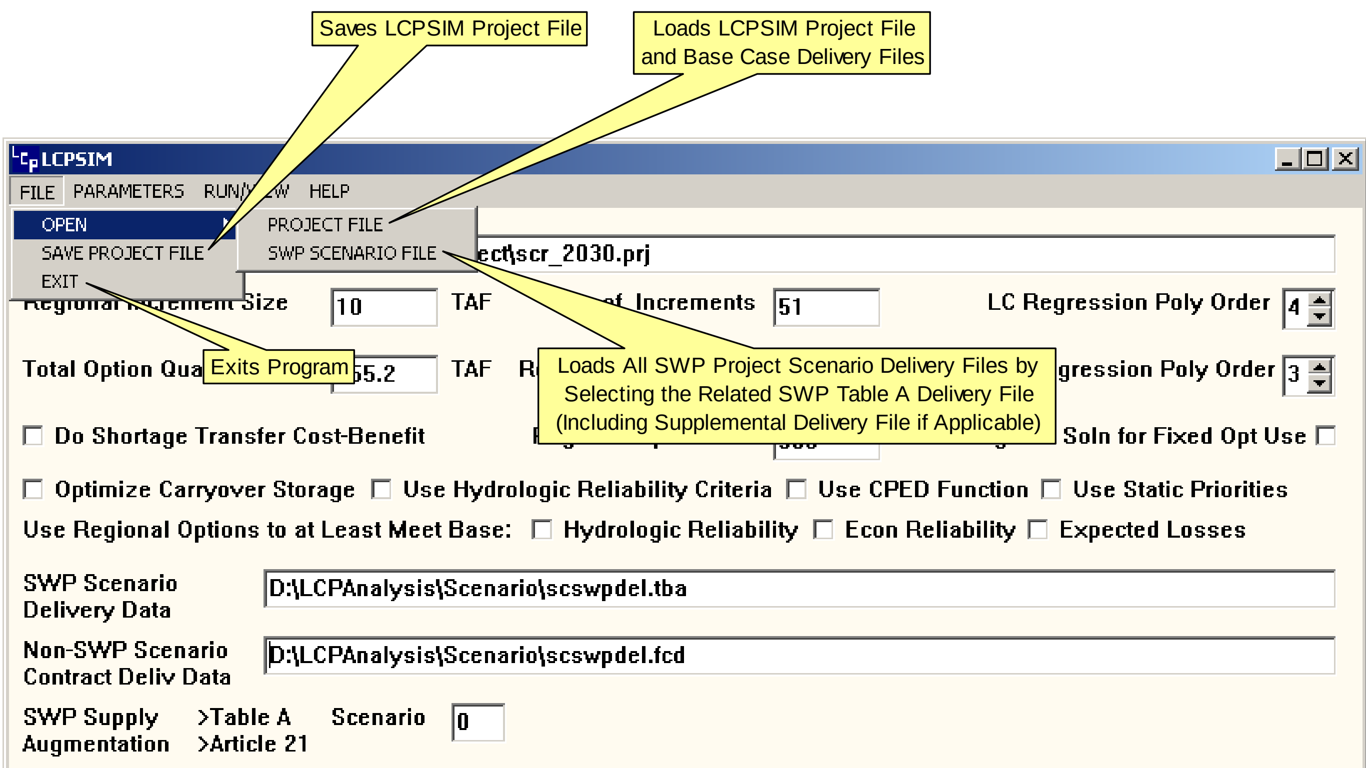
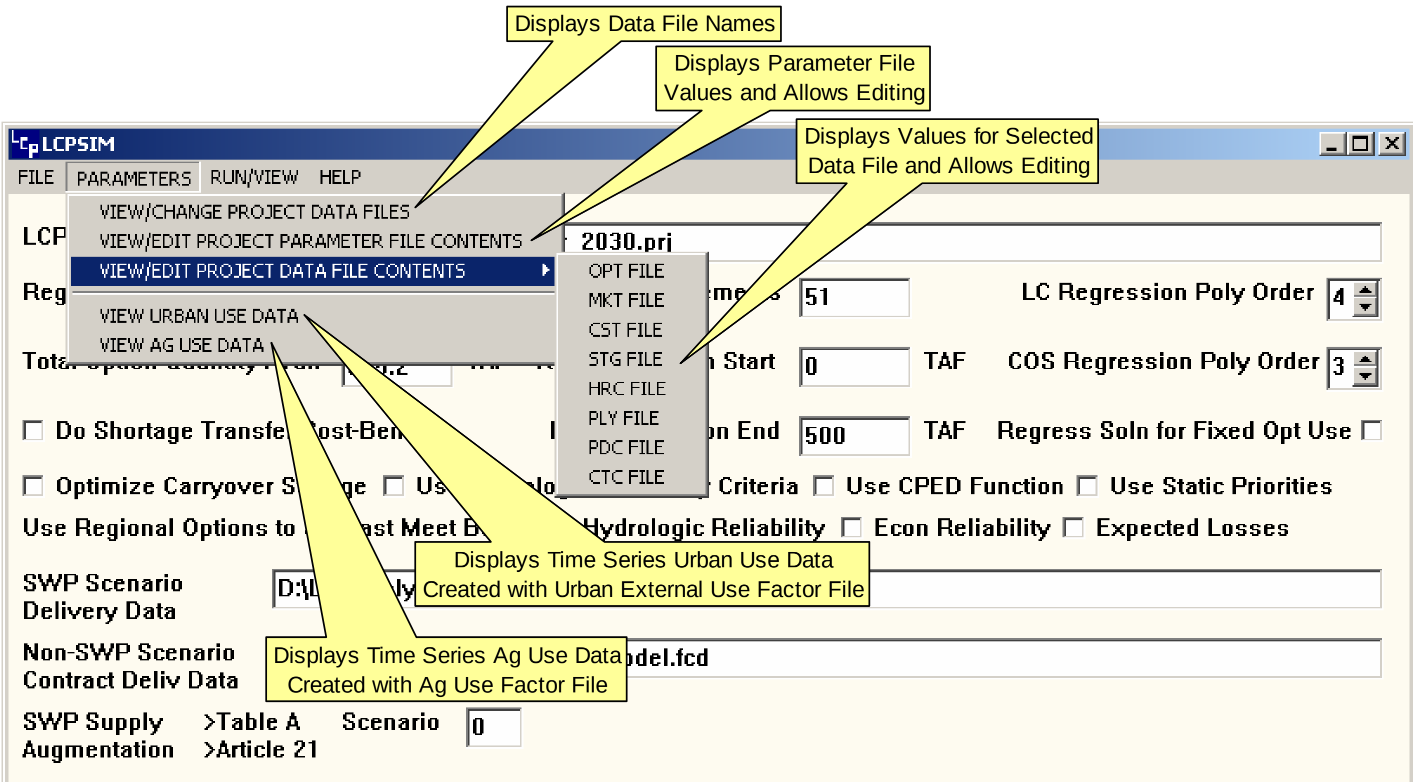


Figure B-5. Parameter Menu



DRAFT

Figure B-6. Data File Screen

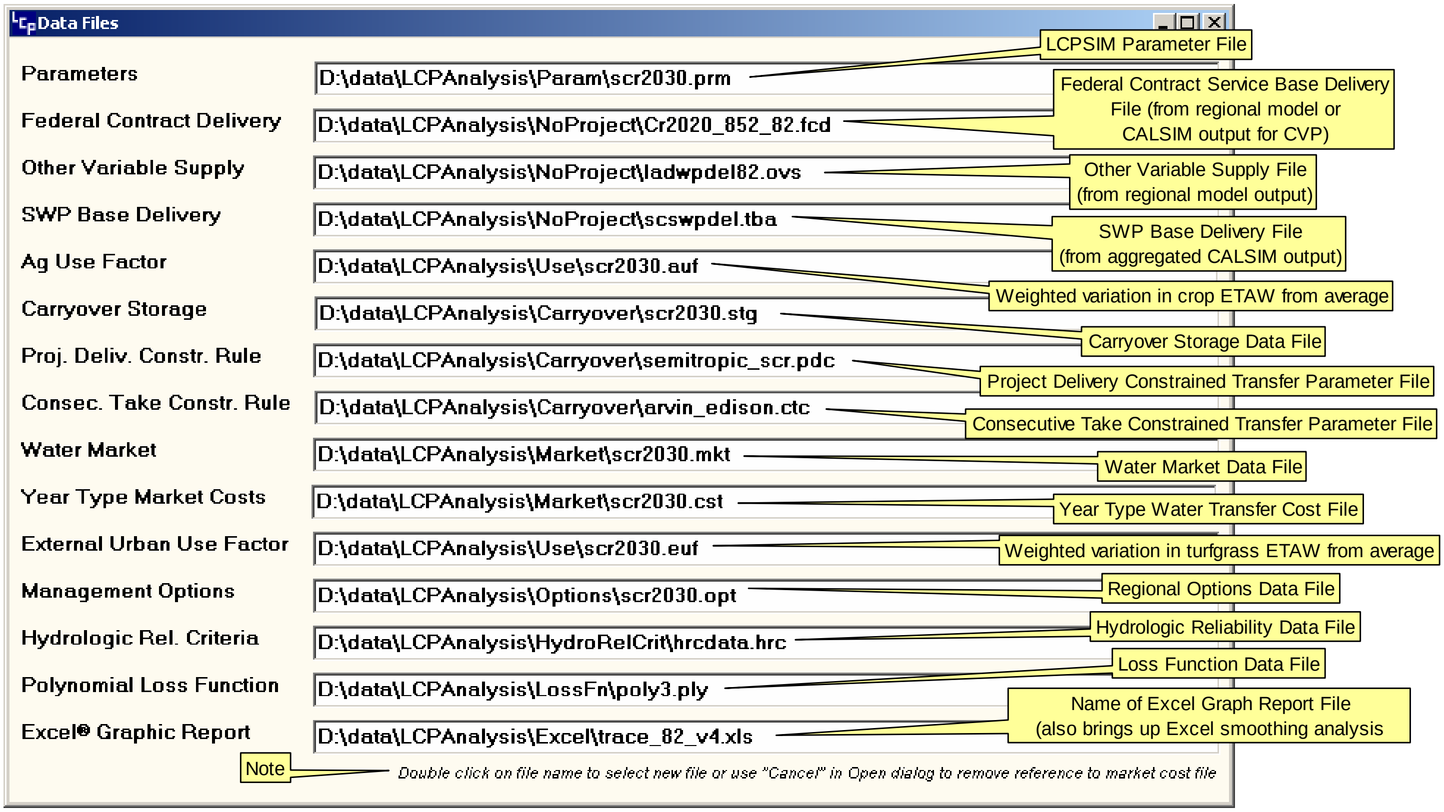
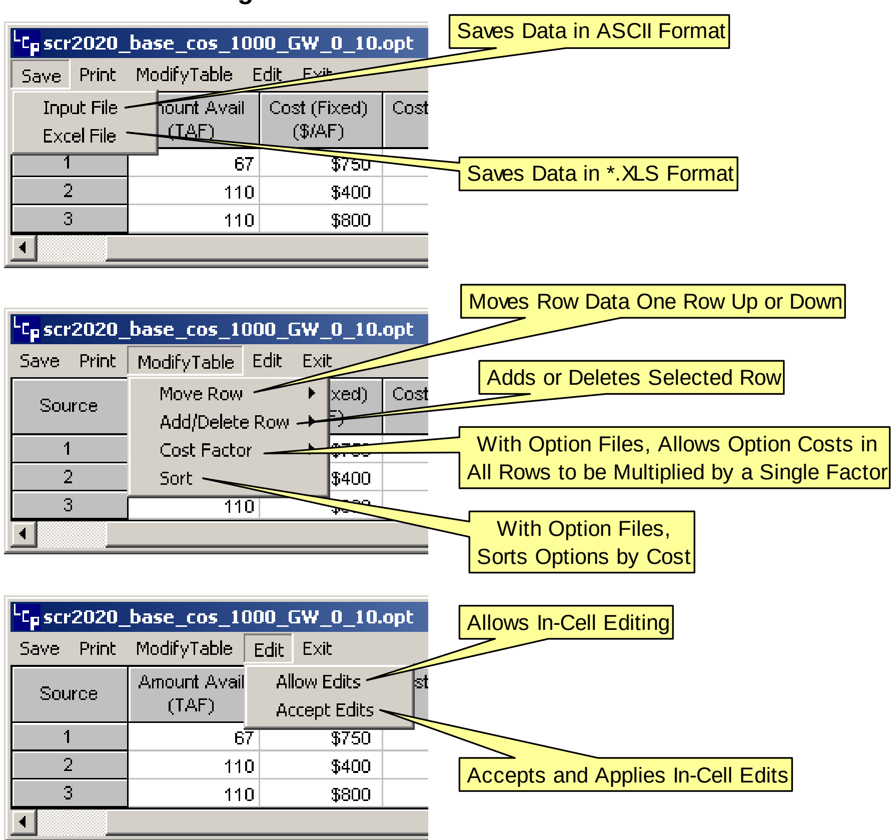


Figure B-7. Data File Edit Menu



DRAFT

Figure B-8. Run/View Menu

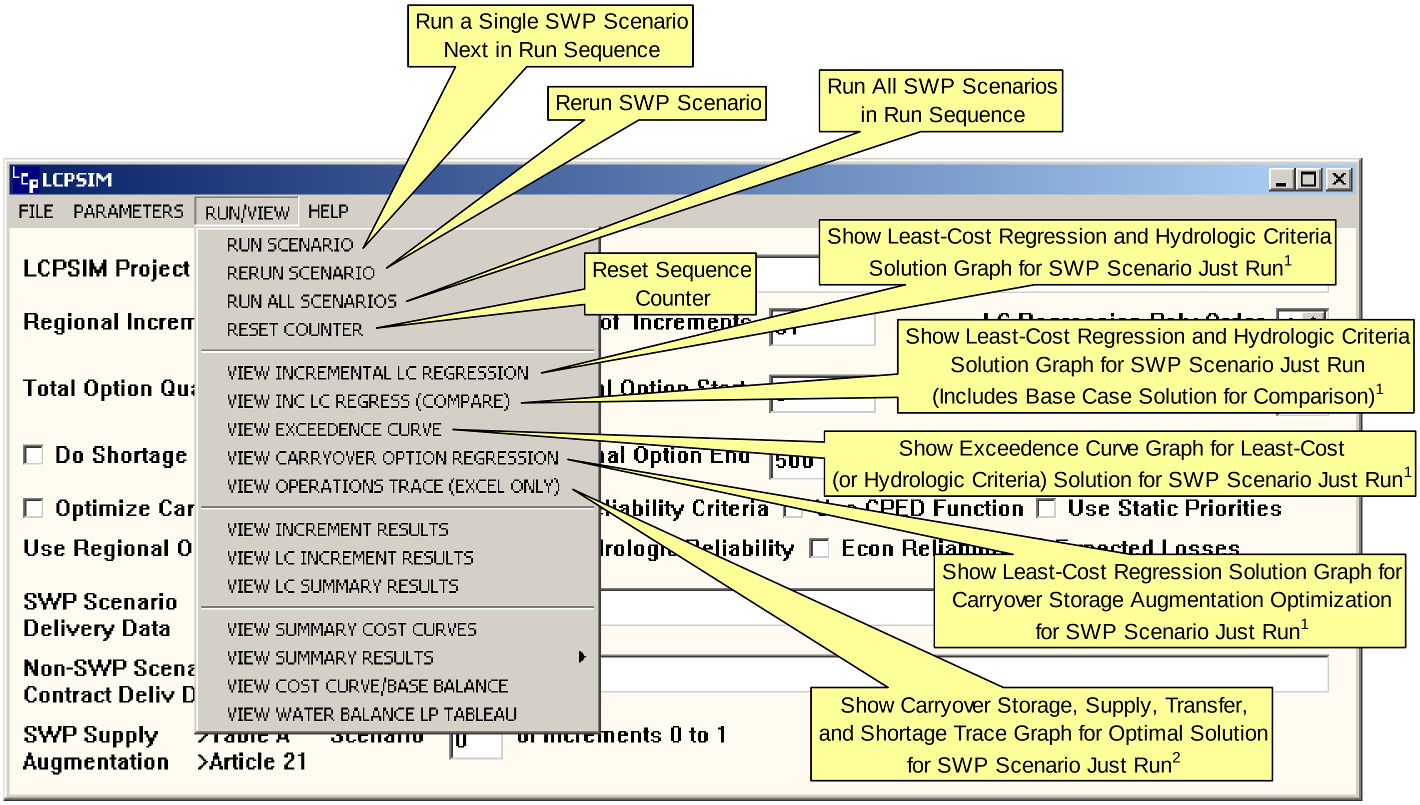


Figure B-9. Run/View Menu (Cont.)

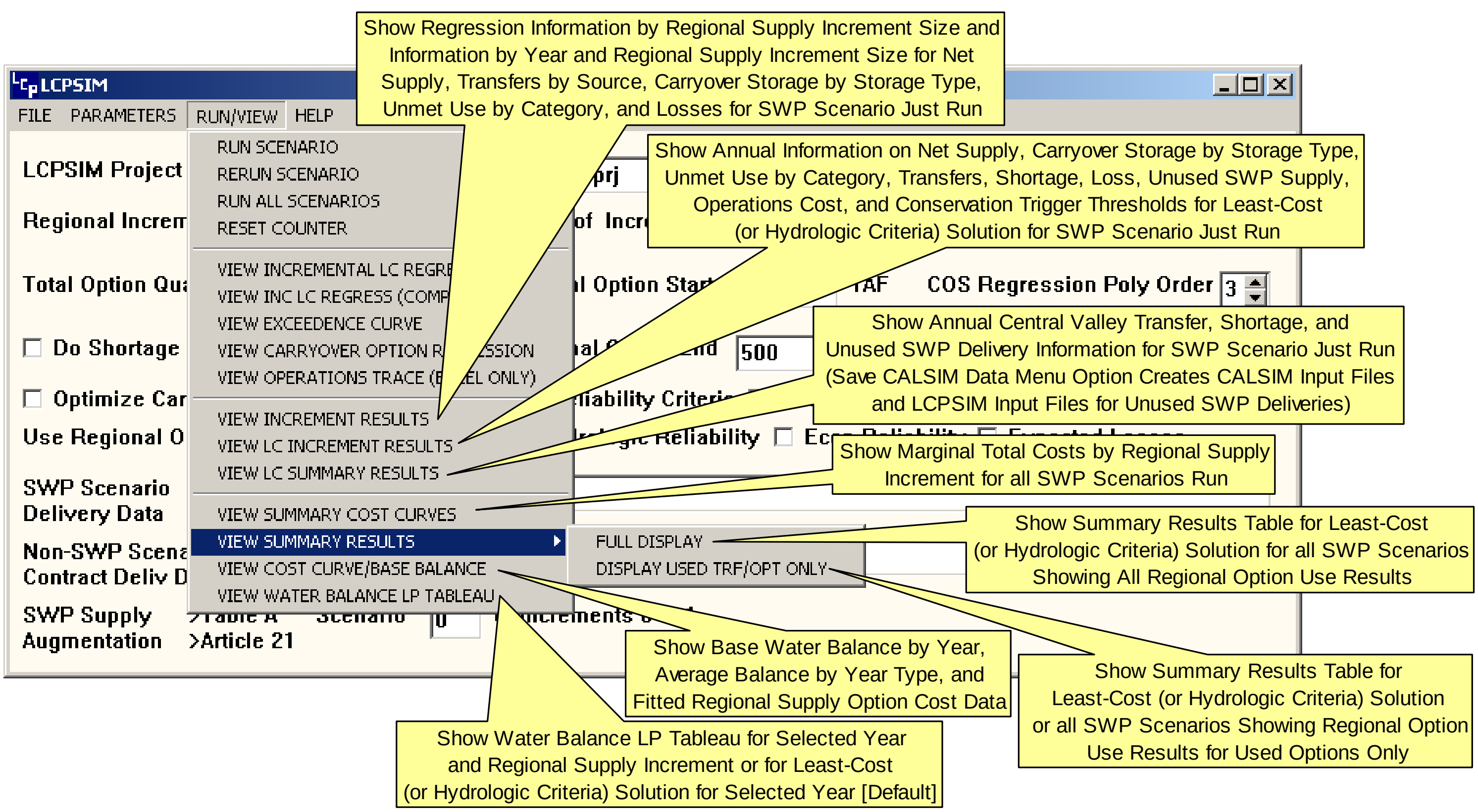
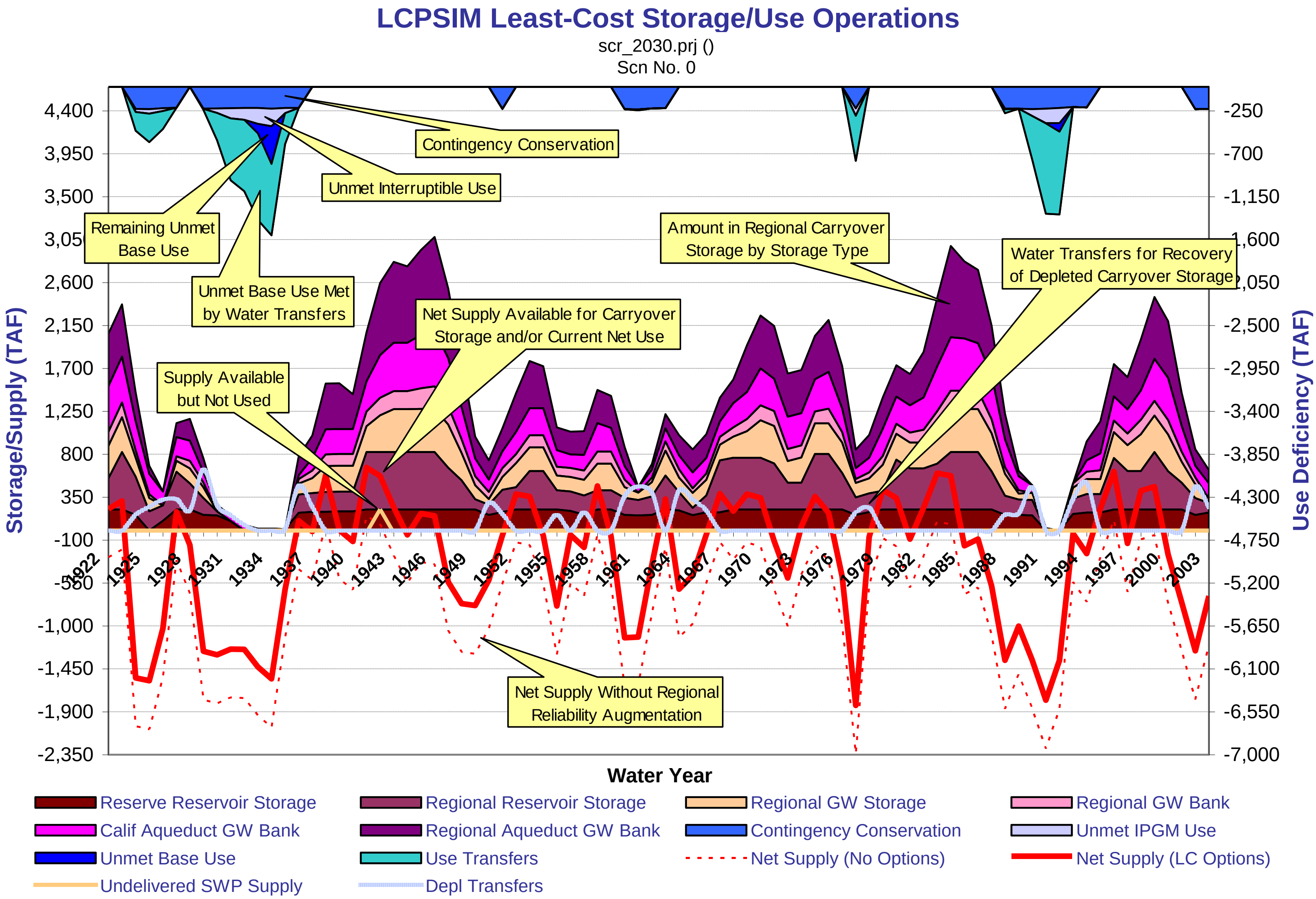
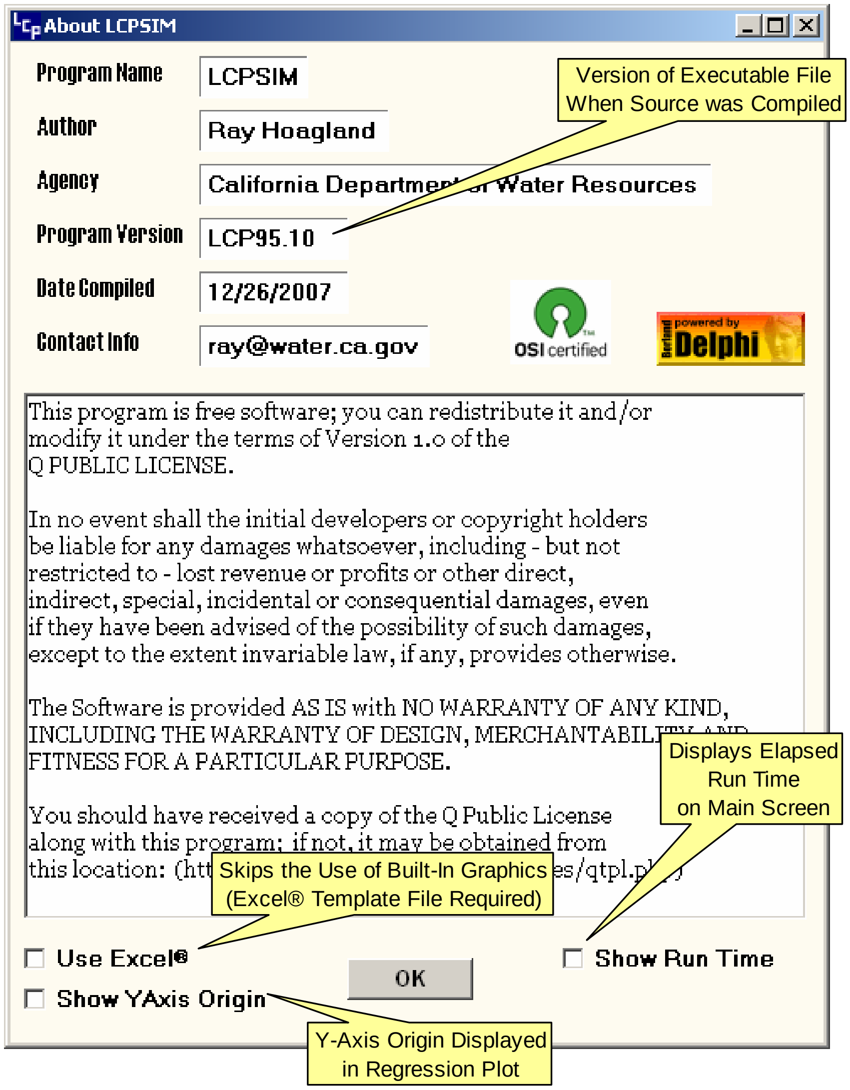


Figure B-10. Example Operations Trace Screen



DRAFT

Figure B-11. About Box



DRAFT

Appendix C

Smoothing Analysis Utility Screens

The following figures depict example screens in the Excel® smoothing analysis utility.

Figure C-1. Example Main Spreadsheet Screen

Smoothing Analysis

	startquan (TAF)	endquan (TAF)
range	600	900

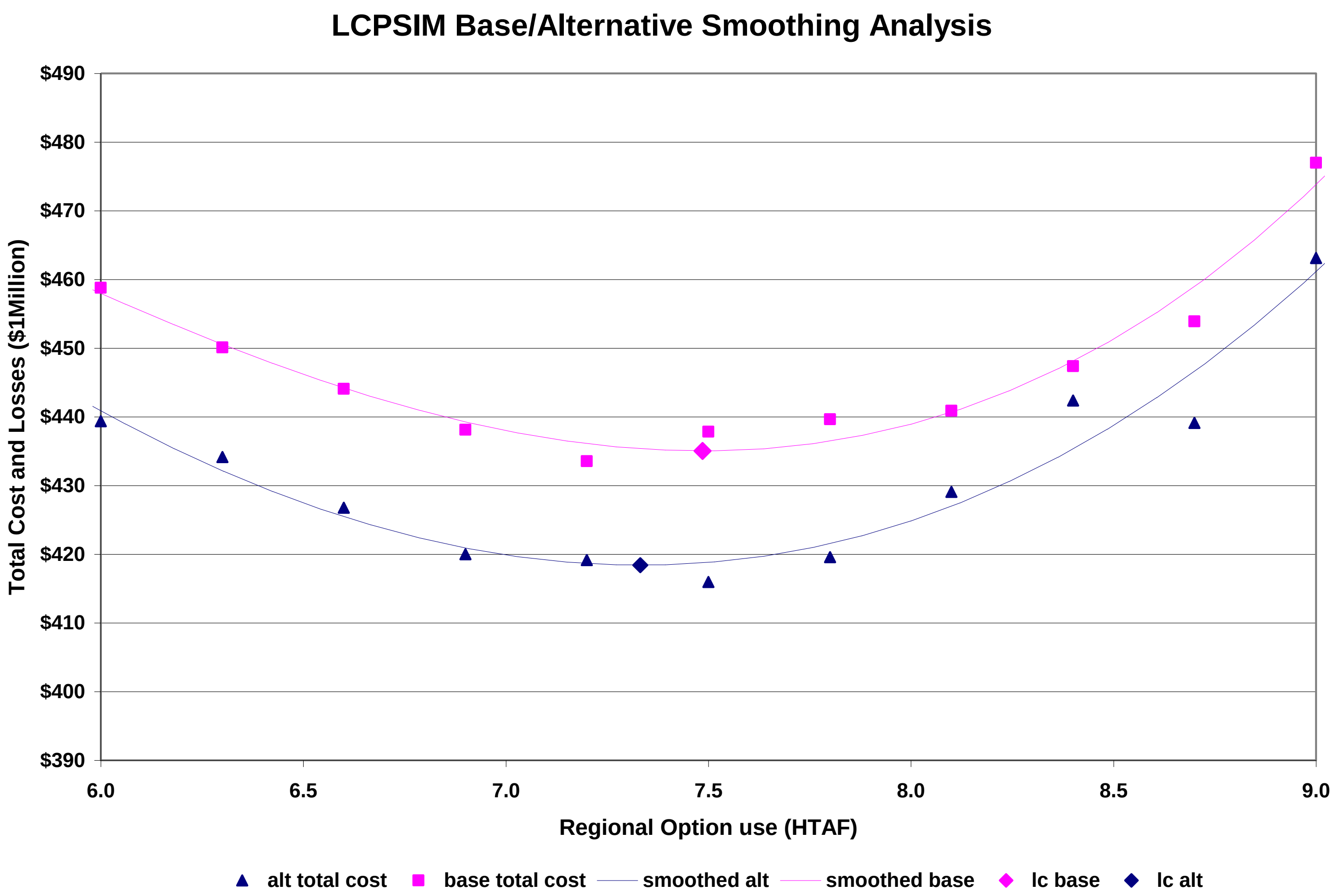
	order
poly order	3

Polynomial Coefficients

	alt_coeff1	**alt_coeff2**	**alt_coeff3**	**alt_coeff4**	**alt_coeff5**	**alt_coeff6**	**alt_coeff7**	**alt_coeff8**
alternative	809.765715	-58.536988	-5.8739061	0.89713958	0	0	0	0
	base_coeff1	**base_coeff2**	**base_coeff3**	**base_coeff4**	**base_coeff5**	**base_coeff6**	**base_coeff7**	**base_coeff8**
base	287.426207	161.093276	-35.136466	2.17091769	0	0	0	0
	ben_coeff1	**ben_coeff2**	**ben_coeff3**	**ben_coeff4**	**ben_coeff5**	**ben_coeff6**	**ben_coeff7**	**ben_coeff8**
benefit	-522.33951	219.630264	-29.262559	1.27377811	0	0	0	0

	lc point (HTAF)	lc value ($Million)	Residual Variance
alternative	7.33	$418.41	19.39
base	7.49	$435.05	9.10
benefit		$16.64	21.76

Figure C-2. Example Smoothing Analysis Results Graph



DRAFT

Appendix D

Regional Urban Water Balance Analysis

The following figure is an example of the application of a regional urban hydrologic balance modeling tool that was developed in Excel® for the purpose of setting some of the water use and reuse parameters LCPSIM. The model solves for an urban regional water supply requirement from within-region urban applied water use after accounting for regional reuse. DWR Water Plan Update water portfolio data are used for calibration.

Figure D-1. Example Regional Urban Water Balance Modeling Tool

Parameters	base	recalc	change	% change
conveyance dp / applied	0.0%	0.0%	0.0%	0.0%
conveyance e&et / applied	0.0%	0.0%	0.0%	0.0%
conveyance outflow / applied	0.0%	0.0%	0.0%	0.0%
interior applied (TAF)	2,956.5	2,956.5	0.0	0.0%
etaw of exterior (TAF)	1,463.6	1,463.6	0.0	0.0%
etaw / exterior use	80.0%	80.0%	0.0%	0.0%
exterior dp / ex dp & ex flow to ss	33.9%	33.9%	0.0%	0.0%
interior deep perc / interior	3.0%	3.0%	0.0%	0.0%
reuse of deep perc	98.0%	98.0%	0.0%	0.0%
dedicated recycling (TAF)	470.0	470.0	0.0	0.0%
recycling dedicated to exterior	86.7%	86.7%	0.0%	0.0%
reuse of surface return (TAF)	38.1	38.1	0.0	0.0%
e&et of wastewater / return flow	2.1%	2.1%	0.0%	0.0%
Results				
exterior outflow to ss (TAF)	241.9	241.9	0.0	0.0%
exterior deep perc (TAF)	124.0	124.0	0.0	0.0%
exerior deep perc / exterior	6.8%	6.8%	0.0%	0.0%
total exterior outflow & dp (TAF)	365.9	365.9	0.0	0.0%
total deep perc (TAF)	212.7	212.7	0.0	0.0%
interior applied reuse / reuse	57.4%	57.4%	0.0%	0.0%
exterior applied reuse / reuse	42.6%	42.6%	0.0%	0.0%
supply depend. int. reuse (TAF)	86.9	86.9	0.0	0.0%
supply depend. ext. reuse (TAF)	121.5	121.5	0.0	0.0%
total supply affected reuse (TAF)	208.5	208.5	0.0	0.0%
tot. supply affect. reuse / applied	4.4%	4.4%	0.0%	0.0%
interior use from supply (TAF)	2,752.2	2,752.2	0.0	0.0%
exterior use from supply (TAF)	1,317.2	1,317.2	0.0	0.0%
interior applied (TAF)	2,956.5	2,956.5	0.0	0.0%
exterior applied (TAF)	1,829.5	1,829.5	0.0	0.0%
total applied (TAF)	4,786.0	4,786.0	0.0	0.0%
reuse of surface (TAF)	508.1	508.1	0.0	0.0%
reuse of deep perc (TAF)	208.5	208.5	0.0	0.0%
total reuse (TAF)	716.6	716.6	0.0	0.0%
supply / applied	85.0%	85.0%	0.0%	0.0%
supply (TAF)	4,069.4	4,069.4	0.0	0.0%
losses (TAF)	4,069.4	4,069.4	0.0	0.0%
outflow & flow to salt sink (TAF)	2,541.3	2,541.3	0.0	0.0%

<-- user changeable values

<-- values used directly in lcpsim

<-- user changeable values from Water Plan Portfolio